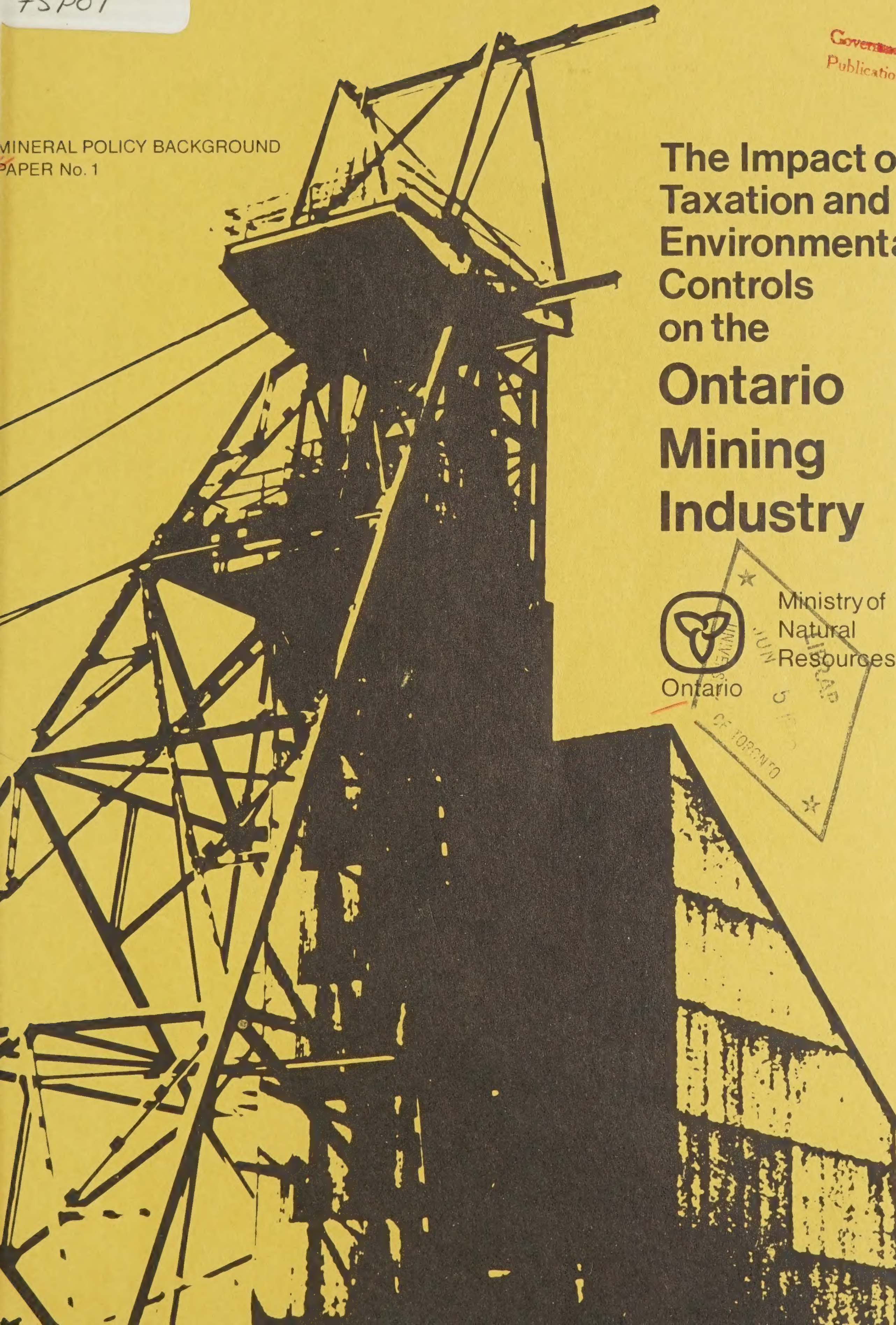
MINERAL POLICY BACKGROUND
PAPER No. 1



The Impact of Taxation and Environmental Controls on the Ontario Mining Industry

Ministry of
Natural
Resources

Ontario

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Note: Opinions expressed in this paper are those of the authors and do not necessarily reflect government policy.

Data used or reproduced are the best available at the time of writing. As the data base improves, the implications of the papers in this series are constantly re-evaluated.

THE IMPACT OF TAXATION AND ENVIRONMENTAL CONTROLS ON THE ONTARIO MINING INDUSTRY

- A Pilot Study -

BY

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GOVERNMENT OF ONTARIO

Mineral Policy Background Paper No. 1

PREFACE

This paper is the first of a series of studies of mineral policy problems to be published by the Division of Mines of the Ontario Ministry of Natural Resources. Subsequent studies will deal with particular issues on a commodity or topical basis.

As this paper introduces the series, it provides, in addition to the treatment of the impact of provincial taxation and of environmental legislation, some broad background information on the development of mining in Ontario, as well as on the political economy and the analysis of mineral industry policy.

This paper is released as the first of a series of data compilations and professional analyses of the mineral industry of Ontario prepared by the staff of the Mineral Resources Branch, Division of Mines, Ministry of Natural Resources. It is recognized that the available data for meaningful economic analysis within the mineral field is limited and sometimes difficult of access. Further studies will attempt to assemble and analyze data on specific commodity areas of the Ontario mineral scene, such as Iron Ore, Uranium and Zinc, etc.

It is in the nature of our political process that issues are debated at various levels. The general reader - and we hope that this will include some of our high school students, the next generation - can obtain a solid grasp from Chapters I through V and IX. An audience interested in probing deeper into some technical issues may do so by working as well through Chapters V, VI, VII and VIII while professionals in the field of resource economics may get added satisfaction from the mathematical appendices B, C and D.

If publication of the series contributes to the public's understanding of and interest and participation in mineral policy debate, we shall consider the enterprise to be worth while.

G.A. Jewett
Executive Director
Division of Mines

CONTENTS

FOREWORD

In the recent past mineral resource policy has been in the focus of public attention and public debate as never before. The body of technical expertise which sufficed to settle points of detail which were discussed in the past failed when fundamental questions of policy formulation were re-opened in the wake of the decline in health of the mineral industry. The situation came to resemble the picture once drawn by the late Frank S. Meyer: "Like a bevy of old wives congregated about the bedside of a suffering patient, every pundit presses his own nostrum, each directed towards a conspicuous symptom; and, as the chatter rises, it drowns the voice and crazes the mind of everyone attempting to assess the underlying malady which creates the symptoms." *

The first steps necessary to restore productive dialogue are to cut through emotion-filled verbiage by specifying key definitions and terminology on the basis of realistic assumptions, then to develop an industry model to facilitate analysis of policy impacts and to carry out such analysis to the extent the available data base allows. *The Ministry of Natural Resources decided to take these steps* using outside consultants as well as in-house capability. The result of our <u>initial</u> efforts is this pilot study, the heart of which is a possibly unique model of Ontario's mining industry.

Through this model are traced the impact of changes in taxation and in environmental legislation, the key policy tools which the Ontario Government uses to influence mineral resource activities.

The analysis takes into account that most of Canada's and of Ontario's metallic mineral products are sold on world wide markets where price is determined by the forces of supply and demand. Historically, price levels have risen and fallen, sometimes dramatically. *No government policy can change overall trends in metal prices other than for very brief periods.*

A new departure was also required in communications. To get miners to talk to economists, and vice versa, concepts basic to an understanding of the mineral sector had to be made plain to the latter and simple economic concepts explained to the former. To get the public to listen to and to interact with either group, the range of issues involved in policy formulation had to be presented in a form that could be understood by all. The presentation thus proceeds at different levels in pursuit of these objectives. Reaction generated will be a measure of success of that experiment.

We hope that this will constitute *a significant step in moving public debate on a controversial subject from exchanges of generalitie and badly substantiated assertions onto a firm basis of sound theory and solid fact* - and not only in Ontario - as well as contribute a little to a bridging of the gulf alleged to yawn between theory and practice.

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* Frank S. Meyer: In Defense of Freedom: A Conservative Credo, Regnery; Chicago; 1962 p. 14.

ACKNOWLEDGEMENTS

This study grew out of a research report which the Ontario Ministry of Natural Resources had commissioned Professor Gramm to undertake early in 1973. Throughout, the encouragement and support of Mr. G.A. Jewett, Executive Director of The Division of Mines and of Dr. T.P. Mohide, Mine Assessor and Director of the Mineral Resources Branch, of the Ministry of Natural Resources, were of inestimable value in assuring successful completion of this pilot project. Members of the Metallic Minerals Section and of the Mineral Economics Section were of great help in assembling data and providing comments suggestions.

Comments and suggestions were solicited and generously provided on a first draft from Dr. M.F. Walmsley, Provincial Secretariat for Resources Development, Dr. F. Frantisak, Ministry of the Environment, Mr. F. Plumb, Ministry of Industry and Tourism, Mr. M.W. Airth, Noranda Mines Ltd. and Messrs. J. McCreedy and D. Craig of INCO. Their co-operation led to many improvements. Some technical advice was contributed by Professor T.R. Saving. The responsibility for any faults remains with the authors alone.

Lastly, the work of Miss Ann Annijczyn and Miss Ann Bond in Toronto and of Mrs. Anna Smith in College Station, Texas, who patiently typed many versions of the paper, is gratefully appreciated.

I. INTRODUCTION

For thousands of years government has interacted with private industry as a regulator and taxer, but even today very little is known about the impact which taxes and regulations have on the decisions of the firm and industry to produce output, employ labour and invest capital. *The purpose of this study was to develop a model of firm and industry behaviour and to apply it to the study of the mineral industry of the Province of Ontario.* The model, developed in Chapter V, is then used to analyze the impact of profits taxation (Chapter VI) and of environmental legislation (Chapter VII) on the individual mining firm and the mining industry of the Province of Ontario.

Today there is much concern and debate in the mineral policy field over future resource adequacy, environmental effects of mineral industry activities and the current contributions of the industry to the public purse. We shall assume as given that it is in the public interest that the mining industry continue to remain healthy for its contributions as an employer, a major generator of foreign exchange and public revenue and as a pioneer developer of the remoter and poorer parts of the country. With the end thus given, the questions remaining are questions of efficacy of means and as such are placed outside the realm of opinion and within that of technical economics.

Joseph Schumpeter suggested that a comprehensive analysis of an economic condition in a society consists of two complementary but distinct elements: the theorists view of the basic features of the conditions of society and what is important and what is not, and the analysts' technique or mental apparatus which suggests propositions or "theories". From the latter, then, he may make clear what changes may well be sought. (1) This view points immediately to the solution of a crucial problem in public policy debate - how and by whom the validity of a comprehensive analysis is established - and this in turn provides the justification for the particular form of this presentation.

Any comprehensive analysis may be challenged on three counts: the realism of its assumptions, the logic of the analysis, and the accuracy of its predictions.

The theorist's view of basic features of the system - here the mineral economy of Ontario-yields the assumptions which underlie the analytical apparatus, the theory proper. These cover not only the distinction of what is and what is not important for incorporation in the model but also the nature of the basic concepts entering it. These assumptions can be stated verbally and are thus open to debate by any economically and politically literate layman. The logic of the analysis, or of the model proper, on the other hand is usually a matter requiring some technical competence. As the rigour of a specific model of a complex problem is in today's economics established mathematically, this aspect of the analysis can only be challenged on mathematical grounds, which somewhat

limits participation in that aspect of debate. Challenge proceeding from alleged inaccuracy of prediction is unfortunately rarely feasible in economics. As controlled experiments are impossible, events will usually be influenced by some factors that were left out of the model. Problems of data adequacy make quantitatively accurate prediction difficult in the first place, and the lag between policy recommendation and result would make such verification practically moot, even if it was possible. *Debate of the analysis thus can proceed on two levels: primarily among the public on the realism of assumptions and primarily among economists on the structure of the model.*

Naturally, there will be cross-currents. Technical analysis may force abandonment of some assumptions or the introduction of unrealistic ones on an "as if" basis. This need not matter greatly, as long as appropriate allowances are made when policy recommendations are elicited from the conclusions. On the other hand, the public may want to discard some of the conclusions of expert analysis on the grounds that their implementation might conflict with more highly valued preconceptions which had been left outside the scope of the economic analysis. However, in neither case would the analysis itself be invalidated. In the first case, greater prudence in policy formation would be indicated, in the second case the analysis would provide a basis for assessing the opportunity cost of extra-economic, normative, elements.

In terms of Schumpeter's dictum, mineral policy debate - not only in Ontario - has proceeded in a vacuum. There were many good papers on particular aspects of mineral economics, but no comprehensive analysis. Economic analysis of environmental legislation was non-existent. This does not imply any criticisms. *As long as the impacts of direct government action upon the industry were small in relation to other influences, such as for instance, world metal prices, there was no need for a comprehensive analytical effort. Today's massive level of interaction, however, does require it.* In the past, when tax levels were fairly low and rate changes quite small, taxation studies dealt mainly with direct revenue effects and ignored effects upon industry structure and profit levels. Under the circumstances such neglect was perhaps justified. Other studies dealing with multiplier effects and input-output relationships on the macro-level dealt only in aggregates and their results where in their applicability limited by this approach. In economics aggregates do not directly react upon one another and statistical correlation is no proof of causal correlation. Such macro-approaches therefore were valid only to the extent that ceteris paribus conditions did not change and that aggregation problems did not enter. In other words, to the extent that we could assume that people would not change their decision pattern and that we did not have to worry about adding apples and oranges, conventional macro-analysis was adequate.

Today we know that in many jurisdictions industries have virtually died out in the wake of massive changes in the parameters

determining their performance. Well known examples are coal in Western Europe, shipbuilding in the U.S.A., aircraft manufacturing in Great Britain. Changes under discussion with respect to mining taxation and environmental controls in Ontario today are potentially likely to affect relative returns to capital and operating constraints to a significant extent. Decisions, which are always made by utility - maximizing individuals, will change and peculiar characteristics of particular commodities or regions may have to be considered. The comprehensive analysis required thus also demands *a new approach to mineral economics: a model that builds from solid micro-foundations up to the analysis of policy effects upon investment decisions and output, revenue and employment levels.*

To sum up the basic concerns that led to this study we may say that changes in order of magnitude in government-industry interaction generated a demand for a comprehensive analysis and that these same changes required an approach which is new to this kind of problem. The assumed desirability of broad-based national debate leads to the particular form of this presentation.

In the following, Chapter II provides the background from which to view the problem in perspective. Chapter III acquaints the non-technical reader with some terms and principles of mineral economics and with the assumptions entering the analysis proper. Chapter IV discusses some facets of government-industry interaction relevant to the sector, that is the institutional constraints to policy making which co-determine what have to be parameters

and what have to be variables in the analysis. Chapter V develops the basic model. In Chapter VI the effect of changes in profits taxation, the only kind significant for the Ontario mining industry today, are traced and in Chapter VII those of changes in environmental constraints. This aspect is not yet exhaustively developed in as far as the analysis of ambient controls could not be incorporated at this stage. Further work on undeveloped aspects is planned for the future. Chapter VIII discusses problems of data adequacy and the preliminary empirical results. Chapter IX summarizes theoretical conclusions, indicates policy implications and suggests lines of further government - industry - public dialogue and of further research. Appendices cover some supplementary material, and provide detailed mathematical derivations for Chapters V - VII as well as the empirical data used.

Footnote:

(1) J.A. Schumpeter: Ten Great Economists, Oxford - Galaxy, 1965, p. 268.

II ONTARIO'S MINING INDUSTRY

It is not the purpose of this chapter to present massive historical statistics. They are available - albeit thus far in raw and dispersed form only - in the annual volumes of The Canadian Minerals Yearbook, published by the Department of Energy, Mines and Resources in Ottawa, of the Ontario Mineral Review, published by the Ontario Ministry of Natural Resources, Toronto, and of the Canadian Mines Handbook, published by The Northern Miner Press Limited, Toronto and from annual reports of mineral industry firms. Rather, it is intended to provide broad descriptive interpretations of the data from these and other sources to highlight facts and problems relevant to policy making from the economist's point of view.

As, however, many of the raw data sources are not easily accessible to readers, some key series - mostly derived from Ministry sources - which form the base for Figures 1 - 4, have been reproduced in Appendices E 1 through E 4. It must be stressed, however, that these Appendices still represent raw data, requiring much checking against and reconciliation with similar series from other sources. Development of a reliable historical data base is one of the projects now under way within the Ministry and this will be made public when completed. At such time, much more detailed analysis of historical trends can be carried out than the overview undertaken below using the currently available data.

Development and History: During the early stages of its

history, Canada's economy was characterized by the dualism typical of the development of similar areas: subsistence farming and the export of goods for which 'finding' was tantamount to production - fur, fish, lumber and precious metals from placers or outcrops of highgrade veins. As most of Southern Ontario is overlain by mesozoic and paleozoic sediments, mineral discoveries in Ontario on the whole began rather late, many of the first and some of the major ones occuring during railway construction through the Precambrian Shield areas of the Province. In 1846 the Bruce copper deposit was discovered and silver was reported from the vicinity of Thunder Bay, in 1866 the first gold was found near Madoc and in 1883 the copper-nickel ores of Sudbury were discovered.

Although not directly related to the growth of metal mining in the twentieth century, mention should be made of the fact that there was some iron ore mining activity in Ontario throughout the nineteenth. This centered around a number of magnetite deposits in the south-eastern and of bog-iron deposits in the south-western parts of the Province. It formed the basis for a number of local subsistence smelters and foundries. The Helen, Magpie and Moose Mountain mines as well as a few smaller ones produced iron ore from 1904 to 1926 but then there was no iron ore production for about a decade and a half while the young Ontario steel industry had to import feed from the U.S.A.

In economic terms, the rush or boom phase of a new country's mineral industry development may be explained as follows: As long as both people and capital are scarce, only the discovery of a

mineral occurrence that can be turned into a valuable commodity with a small amount of labour and investment will attract attention. The apparent magnitude of the return to labour - once a strike has been reported - attracts large numbers of people, and the rush is on. However, many expectations are disappointed, and as labour in the typical early boom camp was usually quite immobile, the relative price of labour declined drastically. As a result, capital is attracted and if deposits extend to depth a conventional mining camp grows. Around it either a viable community develops on a more diversified economic base or the camp may turn into a ghost town if the mineral resources base is too small.

The first precious metal "booms" in Ontario, near Eldorado in Hastings County in 1866 and in the Lake of the Woods area in the late seventies and early nineties as well as the Silver Inlet discovery in Lake Superior in 1868, did not lead to the development of viable communities, and the future of some other areas was far from certain. The major precious metal camps in Ontario only came in after the Sullivan camp in British Columbia was well established and after the Klondike rush had passed its peak in 1900: 1903, silver-cobalt at Long Lake (Cobalt); 1906, gold at Larder Lake; 1908, gold in the Porcupine area; 1911, gold at Kirkland Lake and 1925, gold near Red Lake. This was the end of developments essentially uninfluenced by any kind of active mineral policy.

The 1930's saw three actions which were to affect Ontario mining profoundly. In 1934 the United States froze the gold price at $35 per ounce. Although this was counteracted to some extent

in Canada by the Emergency Gold Mining Assistance Act which came into force in 1948, the long run effect on gold mining activity was depressing. In 1936 an amendment to the federal Income Tax Act exempted new producing metal mines for three years. This was a powerful incentive, but it was recently revoked and replaced by other provisions. In 1939 Canadian base metal producers agreed to supply the Imperial Government with copper, lead and zinc at fixed pre-war prices and the industry was put on a war footing.

Iron ore shipments from Steep Rock Lake commenced in 1944- although the existence of an orebody under the lake had been predicted in 1897, 1902 and 1925. In 1953 the lead-zinc deposits at Manitouwadge were discovered, 1956 saw the beginning of large scale uranium production at Blind River and 1969 was the year of the zinc-silver discovery of Texasgulf at Timmins, the most significant base metal discovery in Ontario since Sudbury.

The relevant economic changes, which accompanied these events but to which precise dates cannot be assigned directly, may now be outlined. Although time series in Appendices E 1 through E 4 begin in 1900, Figures 1 - 4 plot data beginning in 1906 and regression lines were also calculated beginning in that year. This was done to eliminate, statistically, the influence of the very first years of rapid but erratic growth.

Figure 1 shows levels of average annual direct employment in Ontario metal mining (this equals man-years worked) and annual physical output in tons of ore hoisted as well as the trend lines for both series.[1] Note that both series shown in the graph combine

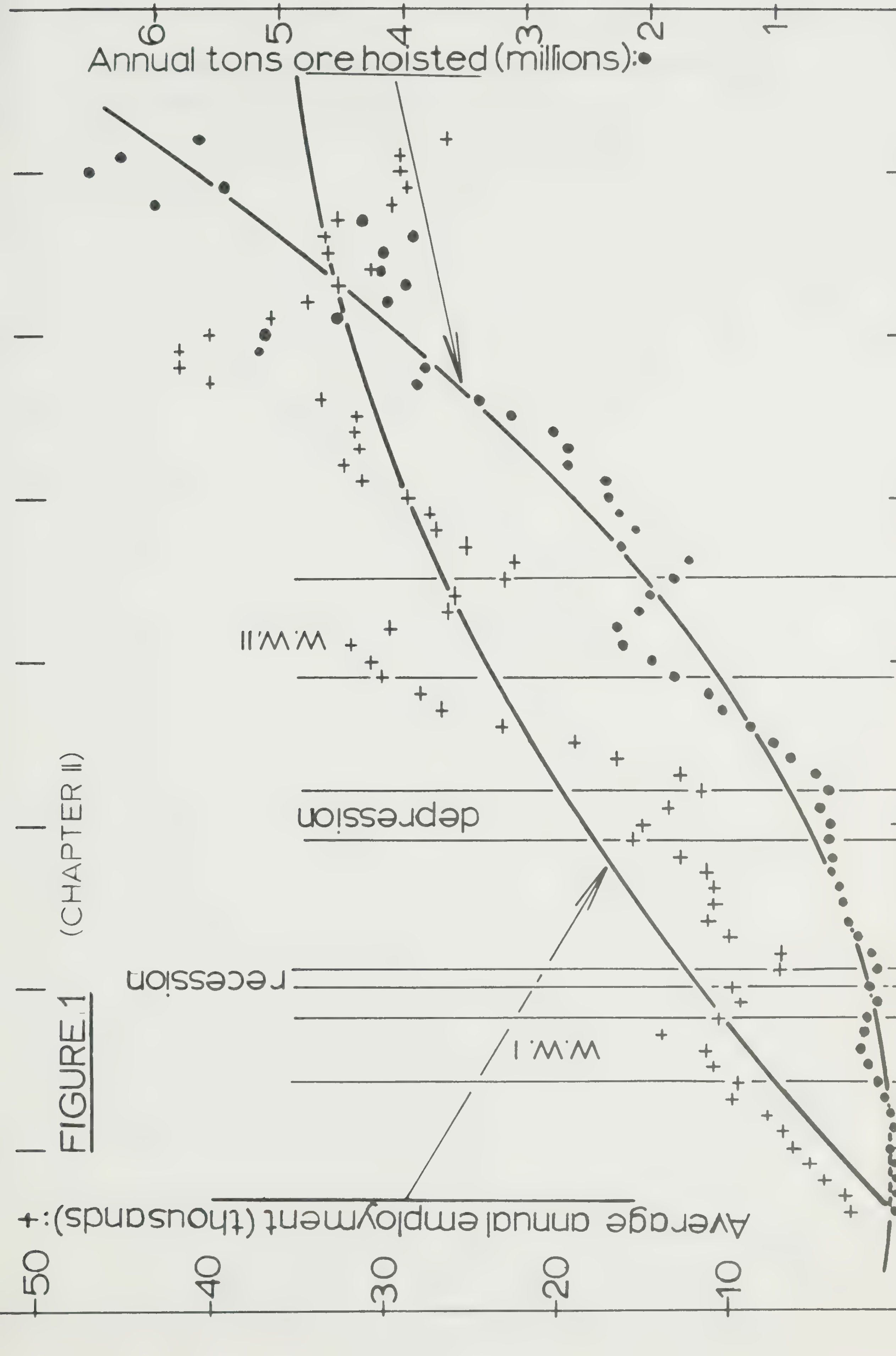


FIGURE 1 (CHAPTER II)

precious and base metal data. The first thing to be noticed is that while tonnage increases at an increasing rate, employment increases at a decreasing rate. Secondly, during both world wars rapid growth during the first years was more than offset by decline during the last years. Thirdly, although declines during the 1920-21 recession and the 1929-32 depression clearly show, the years between 1922 and 1929 showed healthy recovery and between 1932 and World War II the most spectacular growth up to that time occurred. The industry recovered in the late forties and in the fifties from the past World War II slump, the decline of the early sixties in both employment and physical output ended in a remarkable recovery as far as output was concerned while employment trends continued to decline.

If we look at the data series disaggregated into precious and base metal mining in the Appendix, it may be noted that precious metal mining generally employed more persons than base metal mining from 1921 to 1950 and that prior to the second war during recessions precious metal mining showed increased and base metal mining decreased activity. This accords well with what would be expected on the basis of Austrian cyclical theory; there may be a lesson here for the future. As regards the relation of physical outputs of precious metal mining to base metal mining, the ratio increased from about .01 to 1 from 1904 to 1918-19. Until 1940 the ratio fluctuated, generally remaining above 2 and going almost to 9, then declining steadily to .06 in 1972. The inter-war years were thus the great ones for precious metal mining while over the

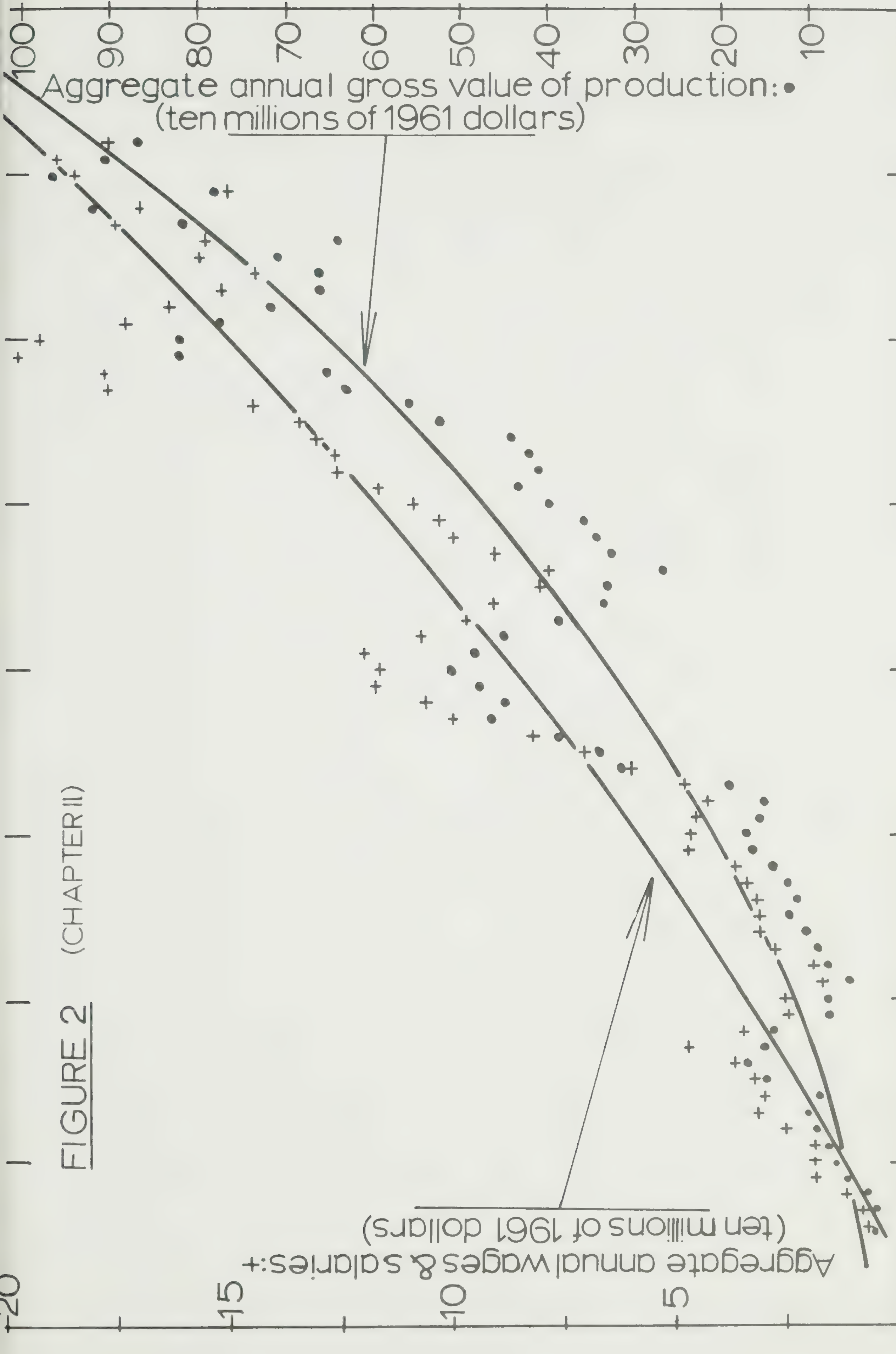


FIGURE 2 (CHAPTER II)

last three decades the dominance of base metal mining steadily increased.

Figure 2 shows aggregate annual wage and salary payments and aggregate annual gross value of production in terms of 1961 dollars. The difference between right and left hand scales should be noted. It is immediately apparent that the two values on the whole have moved together with remarkable consistency. Two caveats should be registered, however. Annual wage and salary payments as shown reflect only direct labour costs. To the extent that during the period shown the relative proportion of indirect wage and salary payments rose, a trend corrected accordingly might be expected to lie above the one shown and to rise somewhat more steeply. Aggregate gross value of production, on the other hand, is based upon metal content of ore mined and a variety of quoted metal price averages. The curve allows neither for processing losses nor for differences of long-term contract prices from spot prices, a corrected curve might be expected to lie below the one shown. Any judgement about relative effects upon extraction efficiency of improved technology and declining grade would be premature at this stage, thus no opinion as to the slope of such a corrected curve is hazarded. More detailed work on these problems is planned for the future.

Again, considering the precious metal and base metal series separately, we see that aggregate salaries and wages were quite close until 1920, when earnings in precious metal mining pulled ahead of those in base metals until the end of the second war.

Since then, there was a steady decline in precious metals, accelerating sharply in 1960, while there was spectacular rise in the base metals, interrupted, however, by two major reversals bottoming out in 1964 and 1969. Changes in output composition, considered in value terms, paralleled those in volume terms discussed above although it may be noted that on the whole precious metal to base metal ratios were larger in value terms than in volume terms from 1906 to 1915 and smaller thereafter.

Figure 3 shows the dramatic decline in average values of Ontario ores, resulting initially from exhaustion of the relatively small high grade precious metal deposits, the discovery of which triggered the boom phase of the first decade of the century; later the decline resulted from the shift in emphasis from precious to base metal mining. Against this must be viewed the relatively lesser decline in direct labour cost per ton. The same cautions as with respect to the data shown in Figure 2 apply. As in many other industries, decreasing per unit spread between labour cost and product value was offset - at least partially - by increases in volume that is because of economies of scale which are reflected in increasing average mine size. In precious metal mining gross values per ton declined from over 300 dollars in 1906 to just over 10 in the late forties and then fluctuated around ten. In base metal mining they moved between 50 and 20 from 1906 and 1941 and between 20 and 15 since then. Corresponding movements in wages and salaries were for precious metals between 40 and 90 dollars between 1906 and 1911 to around 10 in 1915-16; they

FIGURE 3 (CHAPTER II)

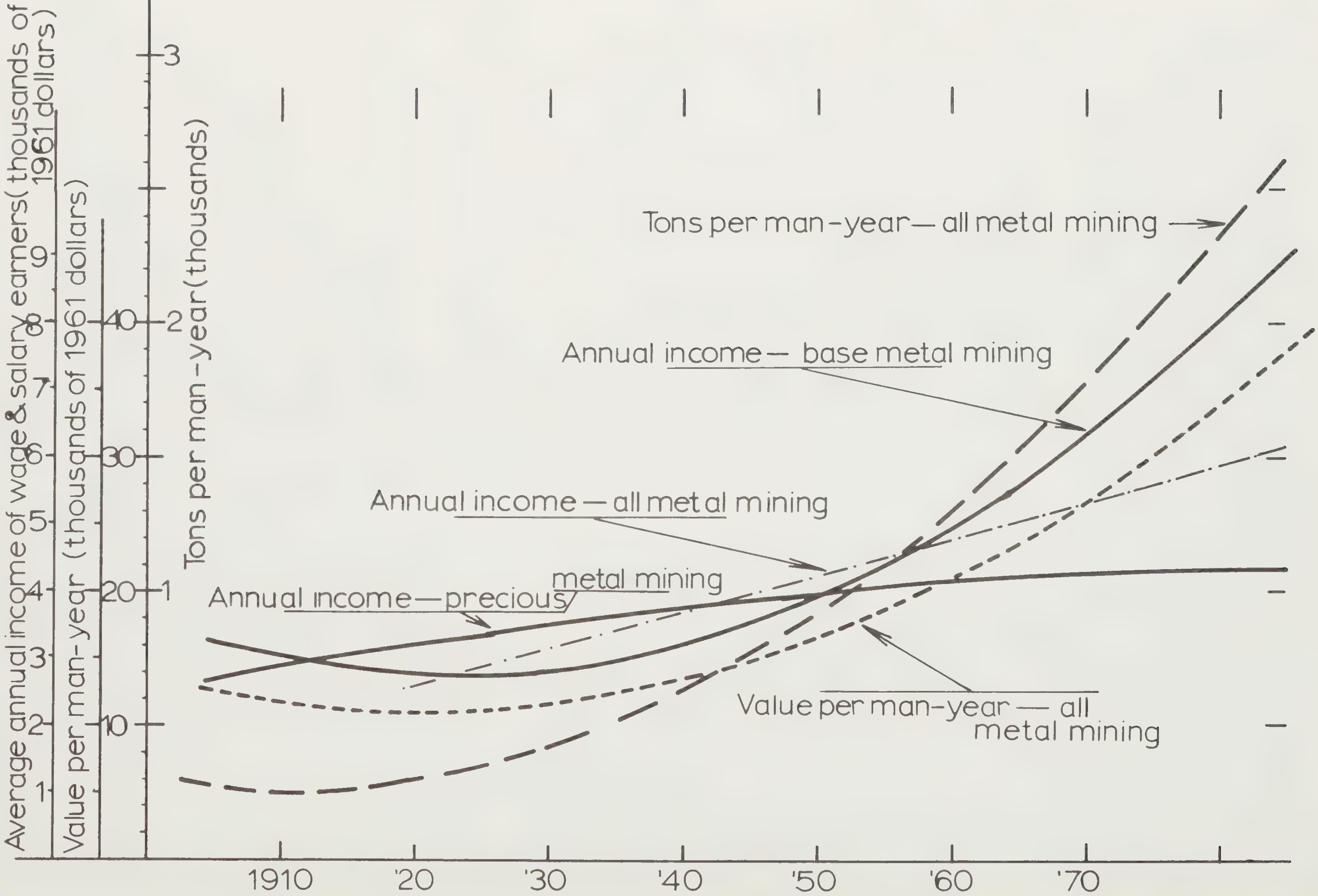
declined to a fairly stable level between 5 and 6 since the late forties. In base metals wages and salaries moved between 10 and 20 dollars from 1906 through 1919, then declined fairly steadily to around 3 in the late sixties. Increases in average mine size were of course far more substantial in base metal mining than in precious metal mining.

Figure 4 shows the substantially consistent relationship between gross value per man year and average annual income of employees; that is between value productivity and return to labour. This occurred, we may speculate, in light of declining values per ton by offsetting increases in physical productivity (tons per manyear) through mechanization - higher capital intensity. The differences between trends of average annual incomes of precious metal mining and of base metal mining employees reflect geological realities which place limits upon the growth of mechanization and of economies of scale possible in typical veintype precious metal mining operations.

After looking at the historical record, we may now attempt to generalize from it as well as from considerations covered in other parts of this report.

Developments may be said to have occured in a logical sequence in four closely interconnected areas. The initial change was one in product which led to changes in the type of deposit primarily mined in the Province. Different deposits required different modes of operation and of technology in prospecting, development and production. These changes - together with concurrent changes in the nature of government - industry relations -

FIGURE 4 (CHAPTER III)



led lastly to changes in dominant modes of financing and in industry structure. While anything but a broad brush review of these areas of change would exceed the bounds of this particular study, a detailed and documented account should present a worthwhile challenge to an economic historian.

The product change that was the cause of all others was from precious metals to base metals or, generalizing further, a continuing decline in the value to volume ratio of ore mined, as mining activity in any particular sector was characterized by continuing shift from higher to lower grade ores. There was, however, a slight reversal of this trend in the sixties which may be considered a strictly temporary phenomenon. As regards type of deposit, the concurrent shift was from veins to disseminated type. And whereas in the beginning prospectors looked for outcrops, today deposits are found under thick overburden. Prospecting moved from labour intensive work on foot to highly capital intensive geophysical and geochemical methods, in the initial stages often airborne and covering large tracts in order to narrow down target areas for more intensive investigation. This in turn required control and staking of large areas. As the value to volume ratio decreased, the average size of mines increased. Even twenty or thirty years ago, 300 to 1,500 tons per day were common mine sizes while today the normal is 3,000 tons per day and more. The individual miner working with jackleg, scraper or mucking machine, and ore train was largely replaced by drill jumbo and scooptram operator. The value of his equipment increased from several hundred or at most

a few thousand dollars to many tens of thousand, even over a hundred thousand dollars. Open pit technology went underground. Mill size and complexity increased as well. These changes, which spelled increasing capital requirements and longer lead times from discovery to production, were in their ultimate effects upon mine financing and industry structure reinforced by concurrent changes in the labour market and in the role of government vis-a-vis the industry. With increasing secondary industry development, opportunities for work in southern urban centres improved. The level of wealth transfers increased across the country. Northern mining communities became relatively less attractive. Immigration fell off due to increasing prosperity in Europe. Minimum wage legislation was passed and levels of unionization rose. A decline in the labour supply to the mineral sector became noticable and marked increases in labour cost resulted which were partly offset by increased mechanization. Federal and provincial tax levels, primarily on profits, increased although the tax treatment of the industry on the whole compared favourable with other jurisdictions. However, there was no capital gains tax. The final result was one of the most highly capital intensive industries in the Province, financed to an increasing extent by internally raised capital and borrowing rather than by new stock offerings.

Products and their Markets: Data highlighting the most important facts regarding the role of Ontario metallic mineral products in Canadian foreign trade are given in Appendices E 5 through E 7. All figures are for 1973, the latest available, and are in current dollars.

Ontario exports about 37% of the ores and concentrates exported from Canada. Nearly 39% of all Ontario ore and concentrate exports are accounted for by nickel exports to Europe, which receives 54% of all Ontario and 36% of all Canadian ore and concentrate exports. Ore and concentrates exports to the United States were 30% of all Canadian and 38½% of all Ontario exports of ore and concentrates. Total exports of refined metals, alloys and semi-fabricated shapes and basic products from Ontario were in value about 40% higher than exports of ores and concentrates, the comparative figure for Canada being about 13%. In this category, about 60% of total Ontario exports go to the United States and about 18% to Europe, while about 61% of total Canadian exports go to the U.S.A. and 23% to Europe.

Metallic mineral sector products amount to about 17% of all exports both on a provincial and on a national basis. If we compare values of exports with gross values of production, they amount to 121% on a provincial and 112% on a national basis. While in these figures the share of ores, concentrates and scrap are 50% and 52% respectively, the shares of further processed categories are 71% provincially and 59% nationally.

Generalizing broadly we may say then that processing beyond the concentrate stage is being carried further in Ontario than in the rest of Canada. The United States is clearly a more important trading partner for Ontario (80% of all exports) than for the rest of Canada (57% of all exports). Of total exports to the United States ores, concentrates and scrap amount to 7%, and to 11% for the rest of Canada.

Taxes and Environmental Legislation: It is not intended here to anticipate either the arguments of Chapters VI and VII or the empirical analysis of Chapter VIII. There are, however, some points pertaining to the distribution of the yield from mineral wealth on which misconceptions abound. In today's climate of opinion it is popular to speak of "the share of the people", that is the proportion of the yield collected by government, generally in the form of taxes.

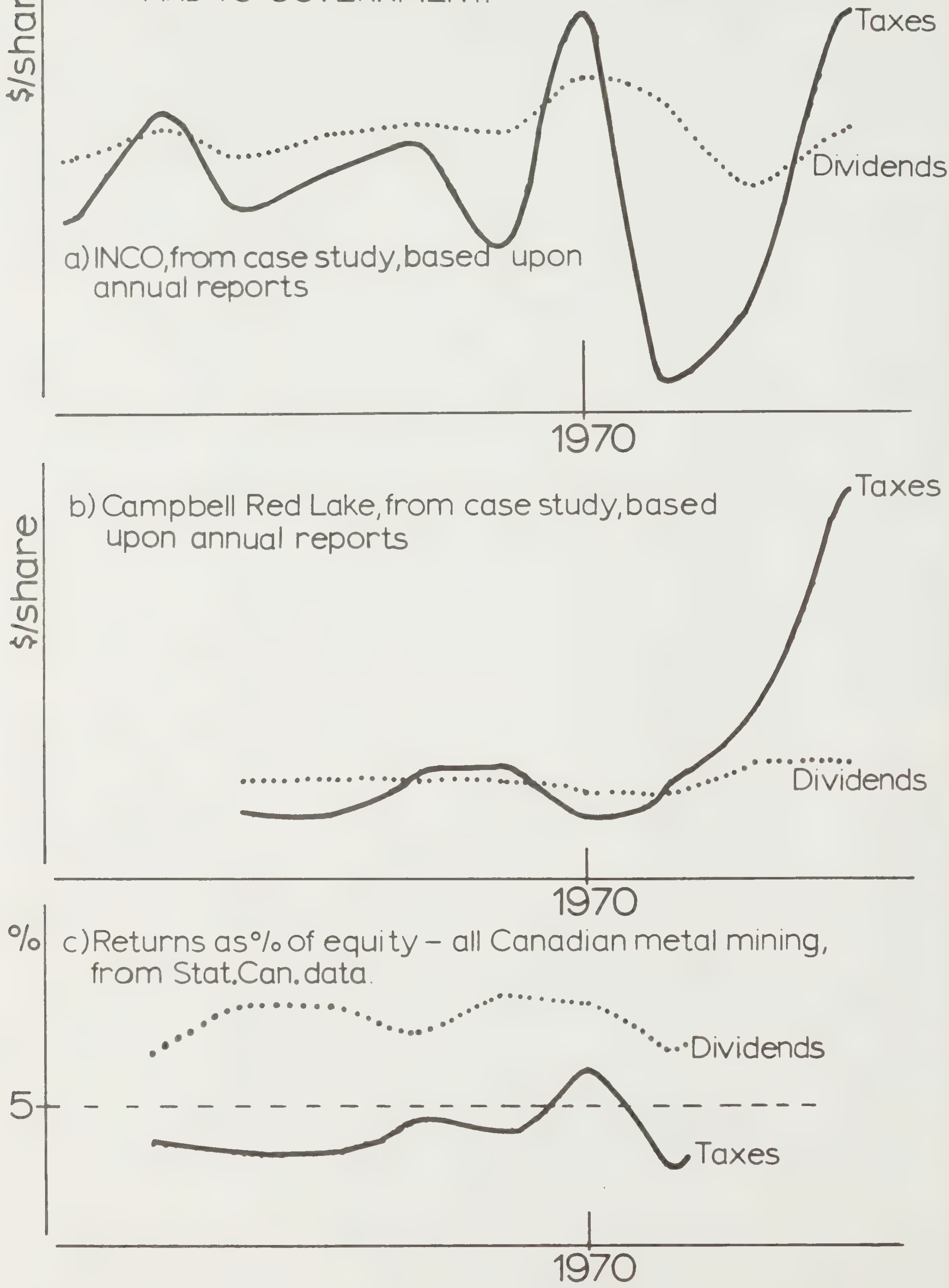
The Provincial government collects mining profits taxes, mining acreage taxes, some royalties, recording fees and miners' license fees, revenue from mining leases and sales of mining lands, while the Federal government collects primarily a corporate profits tax.[2)] The extent to which personal income taxes - whether on wage and salary or on investment income - should be included in the peoples' yield from mineral wealth is still subject to considerable debate. Against this should be viewed the share going to investors, that is dividends. It is sometimes suggested that the investor also has the option to sell his shares, that is to capitalize his future income stream, that he has thus an additional source of income from mineral wealth, at least to the extent that his share value has appreciated. It should be noted, that this option is, at least theoretically, also open to government. But although tax farming has been out of favour and not been practiced for some time in the developed Western nations, there is no compelling reason why some form of lump sum payment in lieu of taxes may not be seriously debated.

If we define the sum of taxes collected directly from corporations (for the present purpose excluding personal income taxes) plus dividends paid to shareholders as, say, the net yield of mineral resource activity, then it appears that the distribution of that net yield between "the people" and the owners of capital has been quite different from what it frequently is alleged to have been. The results of some preliminary case studies and of some Statistics Canada data have been plotted in Figures 5 and 6 to illustrate this point. The two companies selected both conduct the bulk of their operations in Ontario. Both are well established. INCO is a good example of a large, diversified corporation while Campbell Red Lake may be considered representative of a small, single mine corporation. In the figures, axes have not been calibrated at this stage, to avoid giving an impresseion of non-existent accuracy. However, the relationships may on the whole be considered reliable.

From Figures 5a and 5b it is apparent on the one hand that taxes fluctuate more than dividends and that taxes per share have been rising steeply since 1971. INCO, over a 10 year period, paid about 55% of total yield - as defined above - in dividends and 45% in taxes while for Campbell Red Lake these percentages were the reverse over an eight year period. Figure 5c indicates that for all Canadian metal mining dividends generally fluctuate around 7½% of equity annually and taxes between 2½% and 5%. The apparent difference in distribution of yields may probably be attributed primarily to the facts that the all Canada figures include many

FIGURE 5 (CHAPTER II)

RETURNS FROM METAL MINING TO SHAREHOLDERS AND TO GOVERNMENT.



operations less successful than INCO and Campbell Red Lake and that they include as well quite a few mines operating in their three-year tax-free periods (a provision that has been abolished). Figure 6, again based upon the preliminary INCO case study indicates (the fit of the staight time regression lines shown was not good at all) that at net earnings below about 110 MM $'s dividends are usually higher than taxes while at net earnings above about 150 MM $'s taxes generally exceed dividends.

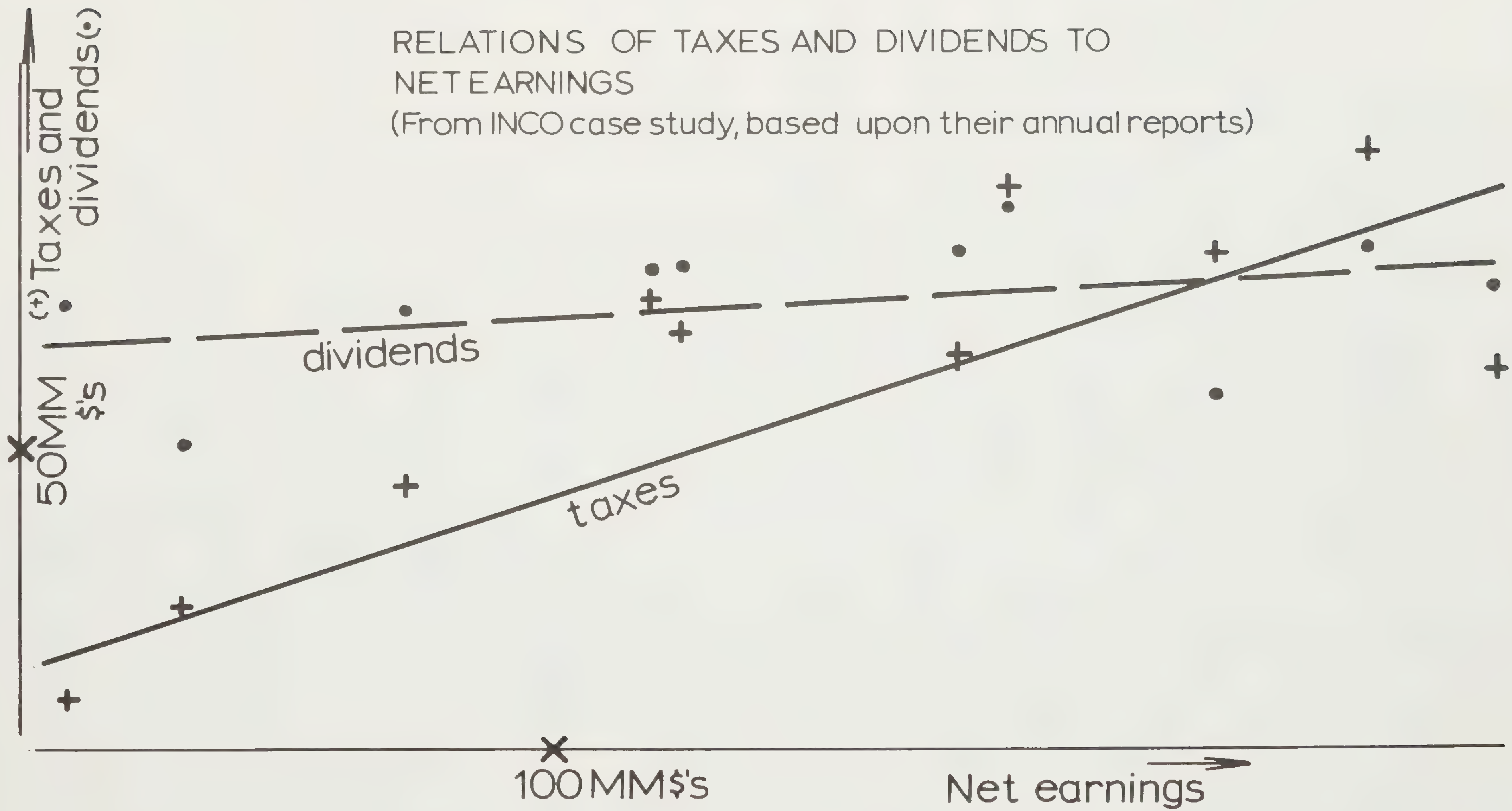
At the least then it appears on the basis of preliminary studies that shares of "net yield" going to owners and to non-owners of capital have been much closer than has been generally supposed.

Major comprehensive Federal legislation pertaining to the environment was enacted in 1970 (Canada Water Act) and in 1971 (Clean Air Act). Major Provincial Legislation is embodied in The Environmental Protection Act (1971) and The Ontario Water Resources Act (1970). There are many provisions for the protection of the environment incorporated in other Provincial Acts, such as The Mining Act, The Petroleum Resources Act, The Public Lands Act, The Drainage Act, The Highway Traffic Act and others. In practice implementation of procedures and setting of standards under the major Federal Acts are carried out by agreement between Federal and Provincial Authorities, and enforcement is generally in the hands of the Provinces.

The industry has, however, carried out work directed at environmental protection, both inside and outside their operations

FIGURE 6 (CHAPTER II)

RELATIONS OF TAXES AND DIVIDENDS TO NET EARNINGS
(From INCO case study, based upon their annual reports)



for many decades. Hollinger Mines at Timmins, for instance pioneered 30 years ago the re-vegetation of tailings dams which today are used for recreation.

FOOTNOTES

1) In this and the following figures with the exception of one straight line trend, data were fitted to parabolic curves which gave on the whole satisfactory fits (i.e. R^2's larger than .90). More work on trend line analysis is planned after time series have been verified and further disaggregated.

2) Apparent discrepancies between the subsequent comments, some Appendix E data, and analysis of Chapter VIII, based upon the latter, are due to the fact that here Federal corporate taxes are included while for the analysis of Chapter VIII only Provincial Mining taxes and Provincial Corporate Income Taxes were used. Federal Corporate Taxes are generally calculated on a different base than Provincial taxes and data are difficult to re-allocate to Provinces in a way that could make them commensurable with the Provincial data for present purposes.

III BASIC MINERAL ECONOMICS

The mineral system, the object upon which mineral policy impinges, can be viewed as a series of activities that begin with unknown physical quantities in the ground and end with final consumption. Activities begin with an investment decision, based upon profit expectations and include exploration for and the discovery of minerals, followed by land acquisition, mine property development, production of crude ores and concentrates, and further processing into primary metals or the equivalent. These raw materials are either sold directly to consumers or fabricated and assembled into consumer products. Used materials are recycled at various stages of the system, and former mine sites and waste dumps are either rehabilitated or abandoned. At each stage, the state of available technology has a critical bearing on the economic efficiency of the operation and the ability to realize new development opportunities.

The mineral industry, the institutional vehicle of mineral system activity, comprises firms engaged in one or more of the steps leading to the primary metal stage or its equivalent. In the production of primary mineral materials, the industry uses mineral occurrences, investment funds, manpower, managerial and technical know-how, and a host of goods and services from both domestic and foreign sources. Ontario's mining industry markets some 60 mineral commodities and many related primary products plus technological expertise in Canada and throughout the world.

As a more fully integrated mineral system evolves, the industry will have greater impacts on the economy, regionally and nationally. It already generates income and employment directly and indirectly through links with other regions of the country and other sectors of the economy. Many communities - think of Timmins, Sudbury, Manitouwadge - depend for all, or nearly all their income on mining or mineral processing. Mineral - based activities - e.g. Hamilton's Steel Industry - influence non-mineral sectors by the purchase of goods and services and by providing raw materials to other sectors. Although a well developed mineral system within a domestic economy is not a prerequisite for regional or national development, the existence of one is indeed an important national asset. For example, virtually all railroad mileage built in Canada since World War II resulted directly from mineral sector developments.

Much confusion and controversy in resource policy debates is due to lack of familiarity with basic principles of mineral economics. As they impose quite definite constraints upon policy formulation, the most important of these are summarized in the following.

Mineral Economics like any other kind of economics rests ultimately on a specification on method, on one axiom, on one assumption on the nature of knowledge and on a limited number of implications and derivations of these basic concepts. Beyond this, agreement on definitions of basic terms is required.

As regards method the unit of analysis is the individual. Only individuals make decisions - how much and what kind of work to engage in, how much to consume and how much to save and invest, what to consume and what to invest, how to respond to changing constraints to their behaviour. *Aggregates, whether commercial (firms) or political (societies) are only sets of relationships between individuals, which have no existence apart from their members.* If these relationships are institutionalized, the institutions again act only through individuals-directors or managers and representatives or officials. *The study of aggregate behaviour - macro-economics- must thus rest squarely on the study of micro-economics; in the present context that means that the impact of mineral policy must be analysed ultimately on the level of investors' and managers', resource owners' and product buyers' behaviour.*

The basic axiom, or action axiom, states that people act to substitute a more preferred for a less preferred state, or in other words, that they will try to minimize adverse and to maximize favourable effects of changes in behavioural constraints. Changes in taxation policies lead to changes in investors'- and managers' - trade-offs between dividend and capital gains considerations; changes in regulations affecting plant operations, e.g. safety or environmental legislation, may lead to differential effects on firm profitability and to shifts in investment capital flows; changes in factor returns, profits and wages, lead to changes in factor employment, capital-labour substitution.

As to knowledge, we assume that no man can predict the future, and that different people have different knowledge gaps. The assessment of future performance of specific mineral industry projects depends

upon knowledge of a host of details of time and place. This imposes severe limits upon any centralized agency to forecast the impact of policy changes in specific terms. *Information, the acquisition of additional knowledge, is not costless and all decisions have to be made in a world of risk and uncertainty,* that is one where both objective and subjective probabilities have to be assigned to future events by industry and government decisionmakers.(1)

Key Concepts and Key Problems

Mineral Occurrence: *A mineral occurrence is an accident of nature,* a piece of the earth's crust in which some element or small group of elements occurs in extraordinarily high concentration. Thus, for instance, the approximate concentration factors (multiples of the average amounts of given elements in the earth's crust) which characterize major Canadian deposits are 60 for average Ontario iron reserves (just under 30% Fe); 10,000 for the copper grade (2.42% Cu) produced in 1973 from Noranda's Horne mine; 15,000 for the zinc grade (4.53% Zn) of Geco's 1973 production and 350 for the average nickel grade (1.5% Ni) of INCO's current Sudbury production. Texasgulf's Ecstall Mine near Timmins produced from 1965 to 1975 26 million tons from an exceptional orebody, characterized by concurrent concentration factors of 30,000 for zinc, 6750 for copper, 1220 for silver and 560 for lead.

Resources: Over a generation ago E.W. Zimmermann suggested that *"the word 'resource' does not refer to a thing or a substance but to a function which a thing or a substance may perform or to an operation in which it may take part,* namely the function or operation of

attaining a given end, such as satisfying a want." Today we differentiate a little further and refer to final or consumer goods, intermediate goods or factors of production, and primary factors of production or resources. A resource is thus typically an input to a production process which yields an intermediate good which in trade is usually referred to as a commodity. A resource cannot satisfy a human want directly, it has to be combined with other factors of production and transformed in the process. Even water is only an apparent exception. In a modern economy it has to be processed and "packaged" as any other primary factor of production. Resources can be used for more than one purpose, but they are also substitutable for one another within wide margins. Primary factors of production are the natural resources proper - e.g. land, minerals, water, hydro-electric potential, etc., - capital, labour and entrepreneurship. Even they are not 'manna from heaven': capital has to be saved out of income not spent on consumption; labour-human capital - has to be raised and trained and kept healthy; entrepreneurship has to be elicited through incentives; and a natural resource has to be identified and developed. A mineral occurrence is not a resource unless there is effective demand for one of its components at a price higher than that at which it can be produced. The preceding will make understandable Zimmermann's famous formulation: *"Resources are not - they become."*(2)

Scarcity: In any production process, the relatively scarce factor is the critical one, and that factor is - except under very unusual circumstances - capital. Everyone needs an income to stay alive -

hardly anyone in the developed countries "needs" to consume all of it for physical survival. Capital, arising out of income not consumed, thus out of individual decisions alone, is the only "resource" that does not require the cooperation of others to come into being, it is the most basic one. As, on the other hand, capital can facilitate a large degree of substitution of other factors of production for one another, it is liable to be in greatest demand. Addition of any other individual factor to a production process always results eventually in diminishing factor returns and then in diminishing product, while more capital can always transform the whole production function; therefore capital is generally the scarcest factor, the one whose supply is more important than any other to any industry and any economy.(3)

Orebodies: An orebody is a specific mineral occurrence that has been transformed into a resource through the application of capital resulting from an entrepreneurial decision. What is, and what is not "ore" depends on the market price for the product and the costs of factors of production. The limits of an identified orebody are determined by the cut-off grade, the mineral content at which recovery of the valuable components ceases to be profitable. There are no orebodies which are limited in all directions by a discrete boundary between highly valued ore and completely barren rock. Movements of commodity prices change cut-off grades. This expands or contracts the limits of an orebody in known border zones. Profit expectations, again influenced by commodity price movements, together with geological probabilities determine the level of

exploration activity, that is the rate at which hitherto unknown limits of mineral occurrences are determined and new blocks of ground classified as ore or waste. Cut-off grade for current production is almost instantaneously responsive to price changes. Reserves are those parts of an orebody which have been delineated in detail through exploration and development work and which are profitably recoverable with present technology under current factor and commodity prices. *The ore-reserves of a particular mine are thus augmentable, those of the world, infinite. It is pointless to identify reserves beyond a firm's or an industry's planning horizon.* It should be stressed that just as changes in costs and prices can "make" ore out of waste rock, they can, moving in opposite directions, turn valuable ore into waste rock.[4]

The Demand for Minerals responds like any other demand to changes in real prices. In anything but the very short run a rise will lead to the development of substitutes, such as the replacement of copper by plastics in plumbing, or to economies in use, such as the introduction of copper-coated conductors in power transmission. A relative decline in real prices will lead to new usages such as the introduction of nickel alloys into building construction for decorative purposes. In the short run, major users react to price changes primarily by adjusting levels of warehouse stocks.

The Supply of Minerals adjusts to price changes in the short run through changes in production levels and cut-off grades of producing mines. In the long run certain types of deposits may shift back and forth between marginal and sub-marginal categories. Such are

for instance the lateritic copper ores of the tropics in this decade or some quartz-conglomerates carrying zinc values which were developed in Western Europe during the '50's.

It should be noted that long-run supply and demand for most mineral commodities are probably less elastic than for typical consumer goods. New mine developments as well as technical breakthroughs in production and usage require, typically, lead times of several years and pricing is generally more complex than for consumer goods. Large quantities are traded on the basis of long-term contracts. There are widely differing transfer prices between corporate units, vertically integrated to differing degrees. Transportation rates are individually negotiated for most transactions and products are traded at many different levels of processing. London Metal Exchange (LME) or other commodity exchange spot or futures prices thus can diverge widely from those at which the bulk of mineral commodities are actually traded. It should here be noted that application of, for instance, an LME price to total metal content of an ore hoisted, although grossly misleading in absolute terms, is defensible only for the statistical analysis of long run production trends or other correlations as long as carried out consistently.

Of the four basic factors of production of the mineral sector, given orebodies are immobile - although potential ones are ubiquitous, - while capital, labour and entrepreneurship are highly mobile and substitutable for one another. Increases in real wages relative to capital costs quickly lead to increased mechanization.

Reductions in profit expectations in one area lead to shifts of

capital and entrepreneurship elsewhere as these two factors appear to be industry specific. A real shortage can, as in other sectors of the economy, only result directly from price and output controls (last year's energy crisis) or indirectly from interference with the supply of labour (decline of coal mining in Europe and the U.S.A.) or of capital (potential effect of some taxation policies) to the mineral sectors.

Conservation: In a mineral economics context the demand for resource conservation today is based on the assumption that higher returns can be realized from a future than from a present sale. It is a demand to forego certain present income from a given asset for uncertain future income. That future income is usually estimated higher by the advocates of conservation who have no stake in the industry than by current resource owners who have such a stake.

In a recent paper (5) it was demonstrated, that to induce a nation or industry to withold production for extended periods "would take some combination of an extremely low interest rate, a large expected price increase or cost decrease, and a very great positive effect of present output upon future cost". The authors calculated present values for fifteen mineral commodities, using different opportunity costs and interest rates, which would have made production holdback economically attractive for the period 1900 - 1973. For example at a 3% discount, crude petroleum would have to sell today at $30.11 per barrel, gold at $1,006.63 per ounce, based on price expectations alone. These figures would increase to $429,000 per barrel and $37,163,672 per ounce

respectively if the average rate of return before taxes in manufacturing is used as a discount rate, to have made stockpiling or non-extraction a viable policy option in 1905. The authors conclude: *"It is important to remember that production occurs because resources held idle yield a lower return than employing resources in the production process. Stockpiling and production holdbacks are not viable economic options for any extended period in a growing society with a high discount rate."*

Environmental Protection: The analysis of environmental protection measures is closely tied to the concept of externality: the possibility of one economic actor transferring at least part of the cost of his activities to another. The demand for environmental legislation can thus have two sources. The first would be the desire to close externality loopholes to industry, to prevent the mining industry from imposing costs on others. The second would be the desire by others to impose external costs upon mining firms by by-passing market processes to convert a resource to an alternative use, usually in the name of some social good. In both cases costs would increase for the mineral and decrease for other sectors. But whereas the first case would constitute an improvement of market process, the second would constitute an infringement, a diversion of factor-returns by a non-market process. An environmental measure directed toward the latter end would have the same ultimate purpose as taxation; differing only in form, trade-offs would appear to be logically justified.(6)

Lastly, we should not forget that demands for excessively low or

even zero - toxicity of effluents from production processes may be considered excessive simply on the grounds that not even the human organism could meet such criteria - thus we breathe air with 21% oxygen and exhale it with 17% and we usually drink water with a few hundred ppm dissolved solids and release it with 20,000 ppm.

Equity in Taxation: In the classical liberal view the role of government is so severely circumscribed that questions as to the equity of taxation hardly arise simply because the amount of revenue to be raised to finance it would be too small to sustain lenghty argument. Today many re-distributive functions have been added to that basic role, the tax-bite has become larger and the trading of charges of inequitable tax treatment has become all pervasive. It is felt however, that a discussion of equity in taxation is beside the point in the present context. It would only lead to a discussion of the equity of redistribution of factor returns by political processes or of the justice of markets. And such a debate - unless conducted on the highest technical level is only too likely to come to resemble medieval squabbles over a "just price". In a Canadian context it is often suggested that the problem can be side-stepped by accepting the principle endorsed by the Carter Commission that for taxation purposes "a buck is a buck is a buck". But this only leads into a different set of difficulties. It would appear to deny, properly, the applicability of the principle of diminishing marginal utility of money in the sense of wealth in general.[7](While each additional unit of a particular, specific good gives me less satisfaction than the previous one, the marginal

utility of additions to my real income stream - with which I can purchase any goods, including leisure - does not so diminish). Additionally, Carter's phrase raises rather complex problems in preventing double taxation: exactly at what stage of a buck's circulation is it to be taxed? When it is earned by an original investor, if and when it yields a return to the enterprise in which it is invested, when the return is paid out in dividends or when it increases the value of the investors equity, or when the original earner spends it? Or is it to be taxed at <u>every</u> change of hands?

These few comments barely indicate the problems inherent in discussion of tax equity. To avoid political or moral discourses, which certainly have their place, we have here to accept governments' demand for revenue as well as the fact that for political reasons of whatever kind they have to be drawn from a variety of sources. *The source of tax dollars we are interested in is the mineral industry and the problem is crudely put, not to endanger future revenue, employment and output potential by changes in taxation and other constraints, the major one of which happens to be environmental control.*

<u>Rent</u>: A lot of heat is generated by the discussion of rent from mineral resources. Economic rent is most broadly defined as any return to the owner of a productive resource in excess of its opportunity cost, (the return it would yield in its most productive alternative employment.) Even at this level of generality, however, rent payments do have an allocative function - assuring that the factor is employed here rather than there, in its highest valued

competing use. It must be emphasized that rent is not a phenomenon that is unique to land, or orebodies, but occurs with respect to all factors of production. Trying to introduce this highly theoretical concept into mineral policy debate raises two major problems.

Firstly, it becomes important to decide *which factor of production is the crucial one* that policy aims to attract or not to frighten away: whether it is *the mineral occurrence* or potential orebody, *the entrepreneurship* which transforms it into a known resource, or *the capital* which transforms that into a producing mine. It may be suggested that <u>if</u> geological knowledge were perfect and <u>if</u> known orebodies were highly specific and <u>if</u> relatively scarce capital were abundant, <u>then</u> re-allocation of rent to the factor orebody would not affect the amount of that factor in existence. As it is it appears that policy may better focus on the effects of "economic-rent control" upon the allocation of the relatively rarer and mobile factors entrepreneurship and capital to assure that they continue to 'turn moose pastures into mines' within the policy-maker's jurisdiction.

But secondly, even if we accept the theoretical relevance of the rent concept with respect to mineral occurrences, this does not imply that rent can be objectively determined in any concrete case for taxation purposes. The value produced by a mine is a joint product of many factors. Any attempt to impute the contribution of any factor outside the market inevitably turns into a scholastic-normative fight over "just price" or "fair" returns to different

factors of production. No improvement appears realistically possible over trial and error market processes. The terms under which they combine factors of production rest upon the subjective evaluation of rent components by actual or potential business partners, and putative rents are allocated prior to investment decisions.

Market-structure: Most mineral products of Ontario - sand and gravel are the most important exceptions - are traded on world markets. No country can for long exploit apparent monopoly situations as there is world wide competion by non-producers for capital and entrepreneurship to supplant current producers. This should be apparent from the preceding remarks on rent as well as from the recent history of the mineral industries of, for instance, Ireland and Australia. None-the-less, it is frequently alleged that the "competitive model" does not apply to the mining industry and that therefore analysis based upon it is lacking in realism of assumptions and misses the point. In support are generally adduced data purporting to prove "excessive" concentration of seller's market power, that is monopolistic market structure.

The first answer to this charge is that there do not exist, with respect to the mineral industries as well as with respect to other industries, generally accepted operational specifications of product, of market and of control to allow a definition of monopoly. Without that, policy debates on the issue of monopoly control become meaningless.(8)

But furthermore, it is not realistic to allege lack of

competitiveness simply because relatively little of the output of the industry is sold in small lots on the London Metal Exchange at spot or futures prices, but changes hands on the basis of long-term arrangements, often among vertically integrated partners, at other than LME prices. It is suggested, that the problem may appear in a different light if the good that is traded is seen not so much as the pound or ton of metal but rather as the development opportunity, the franchise, for mineral production. The terms of the transaction, between the owner of potential resources and the owner of capital, the investment decision, may then be seen as determined by the supply and demand of non-specific capital, of highly specific entrepreneurship, and of ubiquitous mineral occurrences - with units of metal traded at spot prices essentially a by-product.

FOOTNOTES:

(1) Alchian and Allen: University Economics, 3rd. ed; Wadsworth, Belmont, 1972; to Chapter 3.; v. Mises: Human Action: Yale U.P., New Haven, 1963, pp. 92-142.

(2) E.W. Zimmermann: World Resources and Industries: Harper, New York, 1951; p. 7 and p. 15, respectively; also A. Scott: Natural Resources - The Economics of Conservation: Carleton Lib. - McClelland and Stewart, Toronto, 1973, passim, and L. Hurwicz: "The Design of Mechanisms for Resource Allocation; American Economic Review; vol. 63, No. 2; May 1973.

(3) I. Kirzner: An Essay on Capital; Kelley, New York, 1966; and J.M. Buchanan: Cost and Choice: Markham, Chicago, 1969.

(4) D.S. Colby and D.B. Brooks: Mineral Resource Valuation for Public Policy.; U.S. Bureau of Mines, Information Circular 8422, Washington, 1969.

(5) W.P. Gramm and S.C. Maurice: "The Economics of Stockpiling and Production Holdback". Forthcoming.

(6) See Footnote (8), Chapter IV

(7) It may also be viewed as denying a policy function to taxation, but that subject is beyond the scope of this paper.

(8) M.L. Greenhut: A Theory of the Firm in Economic Space; Appleton, New York, 1970; passim.

IV GOVERNMENT - INDUSTRY INTERACTION

Mineral policy is the sum of government actions that influence the mineral system. It is constrained by the fact that most mineral commodities are traded on world markets and is thus only one of the determinants of the ways in which the system affects the economy and society generally. There is a large diverse mixture of federal and provincial laws, regulations, practices, programs and agreements that affect the use of minerals to satisfy objectives of Canadians as producers and as consumers. Responsibility for mineral policy is shared not only by various levels of government but also in varying degrees by departments within the levels of governments.

The political system within which the mineral sector of the Canadian economy has been operating so far, imposes its own limitations upon policy formulation. Some key principles that have this effect are:

- reliance on everyone's ability to be the best judge of his own interest;
- belief that decision making in society is best widely dispersed because of the impossibility of concentrating all relevant knowlege in one head.
- belief that the future is uncertain.

From these flow that:

- *individuals and firms should be on the whole responsible for their own future*

- *private property should be tampered with as little as possible*
- *the law should be certain and evolve slowly on the basis of reason applied to precedent.*

Many proposals made in the area of mineral policy today would implicitly require the abandonment of this body of interlocking principles. With respect to the mineral sector, the key constraints imposed by these principles - if we do wish to maintain a healthy mineral sector - may be put as follows:

The mineral industries, as others, have born up well under past levels of taxation. But these levels cannot be raised to the point where they amount to confiscation without compensation, or where the flow of capital from the private sector would be drastically reduced. This is one of the major topics dealt with in detail in the following chapters.

While government participation in the industry is wholly compatible with the system as long as it is guided by the ideas of economizing information utilization, reducing transaction costs and contributing to the control of serious externality problems, the merits of extensive participation in development or operation may be questioned for three reasons: Management is more liable to convert potential enterprise profit into increased private utility; innovation is retarded and efficiency adversely affected due to the separation of ownership and control [(1)]; and empirically, attempts in this direction have not worked too well in the past.

Although every government engages in some measure of control of foreign economic relations, excessive interference may well affect capital flows and asset composition in undesirable ways. Relevant here are the critical studies of the long-run effects of mercantilist policy in 17th and 18th century Europe - Adam Smith's Wealth of Nations is still the best treatment - as well as analyses of revivals of mercantilist thinking in this century.(2)

Proposals based upon government's alleged responsibility for the positive management of the country's rate of economic growth are ill-founded. Such proposals rest ultimately on any or all of three major assumptions, all of which are demonstrably unreasonable in the world we live in: (a) the assumption that uncertainty can be significantly reduced by centralizing all economic decisionmaking in very few hands (3); (b) the assumption that any man, when moving into the public sector will be able consistently to act from motives other than individual utility maximization (4); (c) the assumption that allocation of resources according to individual valuations and to factor productivities, i.e. rational resource allocation, is possible outside the market process (5). Government thus cannot have any such responsibility as it is a task beyond the powers of any government.

The best that positive mineral policy can achieve is to compensate for incidental negative effects or to support positive effects upon the mineral sector that results from policies adopted to advance particular goals in other policy areas and which affect mineral industry factor costs and prices; i.e. of fiscal and

monetary, labour and welfare, foreign trade and regional development policies.

The mineral sector of the Canadian economy does not exist in isolation. Policy decisions with respect to it affect, and are in their results affected by, policy decisions in other sectors and by world market conditions. Thus corporate income tax changes affect capital availability generally and allocation between sectors. Changes in welfare measures and in immigration laws affect the labour supply to the mineral sector. Moreover, there is the difficult subject of Federal-Provincial relations. The BNA Act made minerals the subject of Provincial jurisdiction (Section 92). However, other provisions (Section 91) allow the Federal government to intervene. Today the Provinces on one hand may be moving with their mineral legislation into areas in which conflict might develop with the BNA Act provision that forbid interference with inter-provincial trade. On the other hand, the Federal government tends to extend its influence into areas the Provinces consider to be their preserve. To form his own opinion, the reader is referred to the relevant sections (Appendix A).

The ultimate goal of policy: to obtain optimum benefit for Canada from present and future use of minerals is surely acceptable to everybody. But expressed in this form it introduces a good many ambiguities that require clarification or at least awareness before discussion can proceed:

- Is the optimum a sum of dollar amounts or does it encompass non-material factors? If so - how are material and

non-material factors made commensurate.

- How are individual benefits to be aggregated into a benefit for Canada?
- How are expected results from future uses to be discounted to the present?

Fortunately complex questions of political philosophy which are raised by the goal statement need not be answered conclusively to proceed to an appraisal and ordering of the objectives - as long as certain limitations are observed.

There are essentially three options with respect to the main thrust of policy, considering today's popular concerns:

1. *Minerals will continue to be a means to expand and to diversify naturally and gradually domestic economic development.*
2. *Mineral production and mineral exports will be primarily a source of government revenues and will serve a broad range of other social and economic objectives.*
3. *The rate of mineral production and usage will be cut back out of concern for the life-style and well-being of future generations throughout the world.*

In the following, differences and implications of the basic options are sharpened for expository purposes. It must be stressed that most likely any policy adopted in reality would consist of some mix, with elements of one option dominating.

The first option implies continued reliance on market processes and does not involve a change in the extent of income

redistribution. But it is not a do-nothing option, it will require continuous effort to improve the efficiency of the market on a piecemeal basis. This option rests squarely on the record of past policy, which assured on the whole adequate rewards to the private individuals who provided the vitally necessary factors of production-capital, labour, entrepreneurship - under often adverse conditions. In other words, it expects satisfactory future returns from continued exercise of the pioneer spirit which built the country. Continued primary reliance on market processes is the key element. Another implicit one is the belief that generally "when it is not necessary to change, it is necessary not to change."

Although on the whole this first option offers the least scope for positive governmental action there is scope for many strategies of gradual improvement within the confines of the system, particularly through manipulation of tax incentives and limited specific measures in the areas of infrastructure provision, improvements of information utilization efficiency and reduction in severity and frequency of externality problems.

The effect - although perhaps not spectacular - would be a gradual and highly probable increase in the contribution of the mineral industries to all sectors of the economy.

The second option, essentially the one that has become associated with the name of Professor Eric Kierans [(6)], involves an increase by orders of magnitude in governmental wealth transfer activities and would require a complete redesign of the mineral system. This option is based on the assumption that the country's

problems have changed so much in the past decades that the same political environment and the same individual qualitites which made for the industry's past growth are no longer required: that on the contrary returns must and can safely now be re-distributed to large numbers of citizens with no direct connection with or stake in the industry whether as investors, business partners or employees. Rather than the market, political factors are to determine the path of development and the distribution of factor returns in light of prioritites determined outside of goods and factor markets.

This option, with its emphasis on planning and on national political decision making, offers wide scope to government activity. However, the shift in emphasis in policy debate and in the factors influencing decision making from value terms to physical terms which is inherent in the planning element makes rational resource allocation increasingly difficult.

As to the effects of this second option, there is no doubt that in the short run political rewards to proponents and material rewards to non-participants in the mineral sector could be substantial - but both theory and experience teach that the long run costs are liable to be high.(7)

Such necessity to redesign the system from the ground up is also inherent in the third option which is on the whole in line with the thinking on resource problems associated with the Club-of-Rome/MIT study. Massive redistribution of potential mineral sector benefits from this to future generations is its essence.(8)

The overriding concerns are zero aggregate growth and massive

inter - and intragenerational wealth-redistribution on a world scale. The first stems from belief in the limited resources hypothesis, the second from considerations of 'social justice' akin to those underlying the second option.

In addition to the incompatibilities with the system inherent in the planning element of the second option, this option requires a surrender of much national sovereignty. It implies wealth transfer to those who do not contribute to the product of the nation's private sector as well as to those who cannot be taxed at all: non-Canadians and future generations. Although public sector involvement would be greater yet than in the previous option, this would to a considerable extent be by international political bodies. In the eyes of the previous options' proponents, the influence upon the nation's affairs by international corporations would be exchanged for that of international political bodies.

The effects would likely be a decline in material returns from the sector, which would in the eyes of the proponents of the option be offset by substantial satisfactions of a non-material kind.

It may appear to the reader - whatever his preferences - that there is really not much to choose from. But that is simply due to the fact that in today's world policy options reduce to differences in basic values - and not, as may have been the case in calmer times - to differences on the means to reach an unquestioned end.

Discussion over government's role in the mineral sector has thus become heated over the reallocation of net benefits.

For such discourse to be meaningful such benefits have to be defined and related to costs. Internal as well as external constraints to re-allocation and the probable effects of such re-allocations as are feasible within these constraints have to be made explicit. *The way in which minerals are developed and utilized reflects not only the wants of people as individuals within a framework of individual rights but also social and economic priorities of governments and of political groupings throughout Canada. Choices are necessary to implement any change, their range is limited and they impose costs. The important point to keep in mind is that the size of next year's resource pie is in large part determined by the way this year's is divided.*

Footnotes:

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(3) F.A. Hayek: "The Uses of Knowledge in Society": American Economic Review, XXXV No. 4. Sept. 1945. Also the comments on indicative planning in V. Lutz: Central Planning for the Market Economy: Longmans; 1969.

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(6) E. Kierans: Report on Natural Resources Policy in Manitoba McGill University, 1973; and G. Anders: Rent, Communal Property and Economic Nationalism: A Case Study: Ontario Ministry of Natural Resources, 1974.

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V. THE BASIC ECONOMIC MODEL

The purpose of this chapter is to develop a formal model of firm and industry behavior that can be specifically applied to the study of the mineral industry. Such a model must be capable of analysing the impact of Federal corporate income taxes, Provincial mining taxes, and environmental standards on the individual mining firm and mining industry.

Let us emphasize from the beginning that many of the assumptions of the formal model are somewhat unrealistic. This is necessarily so, because in order to be more realistic one must be more specific. That is, as the analyst attempts to describe specific firms or specific industries, the assumptions begin to fit only the firms or industries in question, and the resulting analysis lacks generality, which is what we desire in these theoretical chapters. In any case, the rigorous, formal theory gives us a starting point, a place from which to begin our thinking.

Let us emphasize, however, that *the formal theory provides only a beginning point. It would be a grave mistake to confuse the theoretical model with the real world in which the mineral industries exist. One cannot set policy purely on the basis of the formal model.* Therefore, we will obviously have to change some of the assumption and take a more dynamic approach when considering specific problems, such as the effects of taxation and controls. However, the model will enable us to be specific in our language and will provide a strong framework on which to build our analysis. That is the purpose of setting up the complete model in this chapter. The assumptions under which conclusions -- often

arrived at mathematically -- are reached must be made clear in order for one to understand the nature of those conclusions.

This chapter is divided into two parts: (A), a section dealing with the concept of equilibrium and the process of comparative statics, and (B), a section setting forth the *basic* model of the mining firm and industry. All of the analysis in Section A is set forth mathematically in Appendix B.1, and Section B is shown in Appendix B.2. Therefore, this chapter will consist of basically literary exposition.

V-A. EQUILIBRIUM AND COMPARATIVE STATICS

In the majority of economic analysis first the equilibrium conditions are set forth, then comparative statics are used to deduce the effect of changes in parameters upon the endogenous variables. The equilibrium conditions usually result from the assumptions of maximizing behavior or from a definition. For example, we can deduce that if a competitive firm attempts to maximize profit it will choose the rate of output at which commodity price equals marginal cost, where marginal cost is the addition to total cost occasioned by an additional unit of output. The reasoning is as follows: so long as price exceeds marginal cost, each addition to output (and thus to sales) brings in a revenue (price) that exceeds its cost of production. Thus, profits are increased by producing these units of output. No firm that maximized profit would produce any unit of output for which its marginal cost of production exceeds its selling price. Therefore, the firm produces the output at which marginal cost equals price.[1] This output is called equilibrium output.

From the equilibrium output one can deduce the equilibrium quantities of all inputs also.

Now these are equilibrium conditions in the sense that quantity produced does not change -- in the model -- unless certain things held constant in setting up the conditions change. Those variables that are held constant are commodity price, the prices of inputs, technology, the prices of competitive (in production) products, and so forth. If none of these parameters changes, the equilibrium does not change. Next the theorist is interested in the rate at which a change in one of the parameters changes the equilibrium conditions. To this end, he changes the parameter (mathematically) and observes what happens to the equilibrium output or to the usages of certain factors of production in the model. The sole interest is in comparing the equilibrium values of the variables, not in analysing the path taken by the adjustment process.[2]

A very simple analytical model should clarify the process. Assume that a policy maker is interested in comparing the economic effect of two different types of taxes: an excise tax or per unit tax of a certain dollar amount per unit of sales and an excise tax that is set at a certain percentage of price. Assume that the taxes are set to be the same amount at the original price. That is, if the current price is $20 per unit then a $2 per-unit tax would call for a ten per cent tax on price.

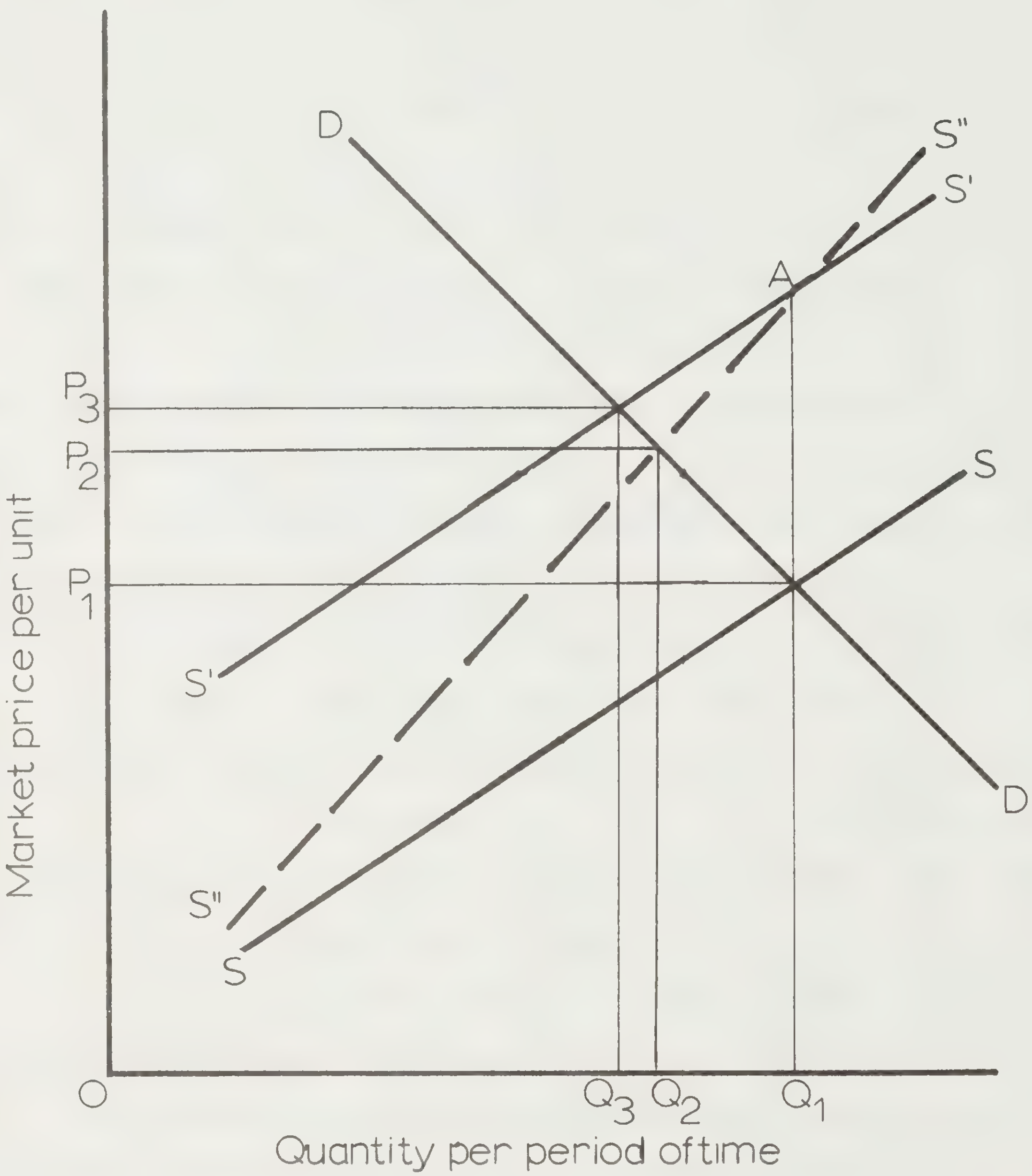
Begin by solving for the equilibrium conditions. Assume that supply and demand in the market are respectively SS and DD in figure 1. Supply slopes upward reflecting that producers require a higher price to get them to produce more. Demand slopes downward reflecting

that consumers will consume less if price rises. For the non-professional reader we might note that *in economic theory supply and demand have very precise meanings.* Supply is a list of prices and the quantities that producers would offer for sale at each price in the list per period of time. Price and quantity are usually assumed to vary directly along supply. Demand is a list of prices and the quantities that consumers would be willing and able to purchase at each price in the list per unit of time. Price and quantity are usually assumed to vary inversely along demand. In Figure 1, DD and SS are the graphs of two such lists. Price is measured along the vertical axis and quantity along the horizontal.

With the given demand and supply equilibrium price is P_1 and equilibrium quantity sold, Q_1. If price were below P_1 consumers would demand more than producers were supplying. The excess demand or shortage would cause consumers to bid up the price. If price exceeds P_1, producers would be supplying more than consumers demanded or were willing to purchase at that price. The surplus, or excess supply would cause price to settle at P_1. Thus equilibrium is attained where supply equals demand.

Now assume that a tax of k dollars per unit is considered; that is, for each unit sold the sellers must give \$k to the government. This tax does not affect demand -- recall the definition. If a consumer demands 100 units of a good per year at a price of \$10 per unit, he does not care whether \$8 goes to the producer and \$2 to the government or vice versa. He demands 100 units either way. But supply shifts upward by the precise amount of k dollars. For example if a price of \$5 induced producers to supply 1000 units per period, with a

FIGURE 1 (CHAPTER V)



per unit tax of $2 producers would require a price of $7 to induce them to supply 1000 units after the tax. That is, they would require a net receipt of $5 regardless of the tax. Following that logic, in Figure 1 supply shifts upward by k dollars at every point to S'S'. Now equilibrium price rises to P_3 and quantity sold falls to Q_3. The extent of the change depends upon the slope of demand.

Now put a percentage-of-price tax on the product. The higher the price the greater the dollar value of the tax and the greater the increase in supply price at the corresponding quantity. Since the percentage was set by assumption to make P_1 increase by k dollars, the supply curves under both taxes intersect at Q_1, the orginal quantity. At lower prices that percent tax yields less of a dollar tax and the new supply lies below S'S'; by the same argument, at prices above P_1 the new supply lies above S'S'. Therefore, S''S'' reflects all of the assumptions about supply under a percentage-of-price tax.

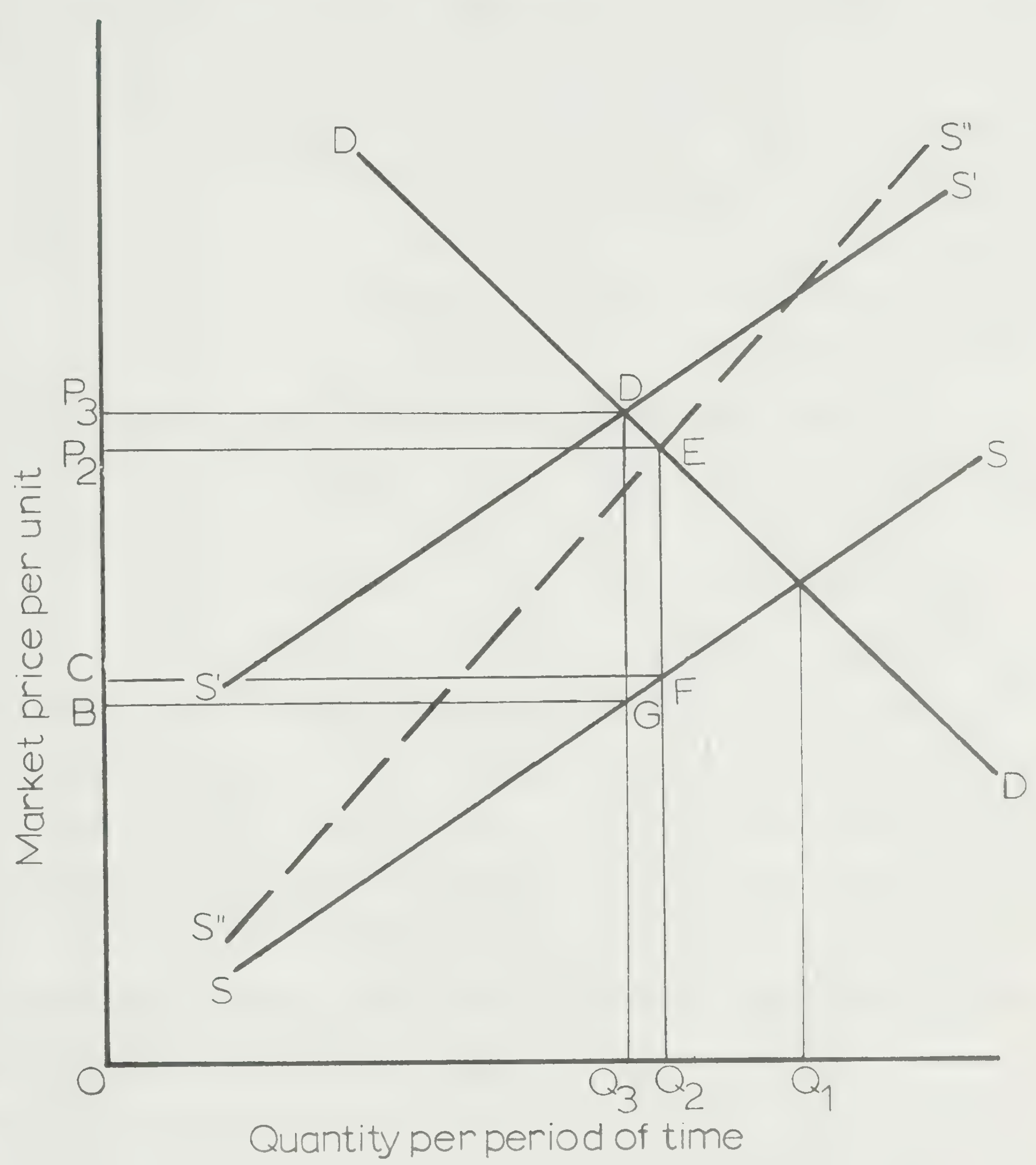
Since the supply curve S"S" lies below S'S' at prices below P_1, it is easy to see that the new price, P_2, that results from the percentage-of-price tax is less than the price, P_3, that occurs after a tax of k dollars. Similarly, the equilibrium quantity, Q_2, after a percentage-of-price tax is greater than Q_3. Therefore, *we can state unambiguously that a per-unit tax raises price and lowers quantity more than a percentage-of-price tax that is set to yield the same tax at the original price.*

While the effect upon price and quantity can be determined unambiguously, the comparison must be qualified in other cases. An example is a comparison of tax revenue under the two assumptions.

Figure 2 is an exact reproduction of Figure 1. The total tax revenue is given by multiplying equilibrium quantity times the tax at that quantity, which is given by price minus the supply price. In Figure 2 the tax rate from the per-unit tax is the distance DG, which equals k. The total tax revenue is given by the area BP_3DG. The percentage-of-profit tax is EF, yielding a tax revenue of CP_2EF. On inspection it appears that the former revenue exceeds the latter, but with different sloped supply and demand curves this need not be the case. Therefore, *the effect upon tax revenue is ambiguous and depends upon the slopes of the curves.*

Even though the derivations are much more complicated mathematically, all of the theoretical analysis in this book will follow the same method of approach as that described above. Some results will be unambiguous while others will change with the values of certain variables. Next let us set forth the assumptions which we impose in developing a theory of mining firms and industries.

FIGURE 2 (CHAPTER V)



V-B. THEORY OF THE MINING FIRM AND MINING INDUSTRY

In subsequent theoretical analysis we will rely in large part upon the basic model of the competitive firm and industry. Justification for use of the competitive framework of analysis has already been argued in Chapter III above. There is no benefit in repeating the arguments here. We begin with the theory of the firm, then proceed to the industry.

V-B.1. THE FIRM

In this model each mineral extracting firm attempts to maximize the present value (P.V.) of its stream of profits, written as

$$(1)\quad P.V.\Pi = \Pi_0 + \left(\frac{1}{1+r}\right)\Pi_1 + \left(\frac{1}{1+r}\right)^2\Pi_2 + \ldots + \left(\frac{1}{1+r}\right)^H\Pi_H = \sum_{t=0}^{H} \left(\frac{1}{1+r}\right)^t\Pi_t$$

where Π_i is the expected profit in the i-th period and r is the interest rate. The firm's profit stream extends from the present, period 0, to period H, presumably the end of the planning horizon. Let us assume for simplicity that the firm expects the interest rate to remain relatively constant throughout the horizon. Note that if we assume (as we will below) that the rate of profit in any one period is independent of the rate of profit in any other period, maximization of the present value of the profit stream requires maximizing expected profit in each period. Given a well functioning capital market this is not an unreasonable assumption.

There may, however, be some objections to the assumption that the firm maximizes profits. Admittedly, there might be other objectives such as the rate of growth (which may not be, but generally is, compatible

with profit maximization), charitable activities, good employee relations, environmental protection, and so forth. These other possible objectives may be ignored here for several reasons. First and foremost, *much of what appears to be non-profit maximization in the short run, such as building goodwill, is perfectly compatible with long-run profit maximization.*

Economists have for years deduced and predicted quite accurately under the assumption of profit maximization. Secondly, many economists, possibly most, seem to feel that the other objectives are relatively unimportant compared with profit maximization. It would be a rather unusual entrepreneur who treated profits cavalierly - particularly in a rather competitive industry like most mineral industries. If some entrepreneurs attempt to divert many resources to other objectives, they will find themselves with higher costs than other firms and will not be able to compete. If some firms attempt to maximize profits, those that do not will possibly go out of business. Certainly some of the most favorably located firms - that is, as far as markets or extraction are concerned - or those blessed with exceptional management will find themselves with lower costs, and those enjoying for a time "rents" to particular factors of production may wish to use some the "rents" to further other objectives. But since it is immaterial how these pure rents are used they can be ignored. For these reasons profit maximization will be assumed throughout the analysis.

In any one period profit is simply revenue less total cost in that period. Revenue is the price of each type of output times the quantity of that type sold in that period. In the present model

we assume also that each firm produces only one type of output. In the case of the mineral extracting firms one could assume that this specific output is some average quality or grade of mineral. Finally, the assumption of a parametrically given commodity price seems quite reasonable for the firm. It seems probable that any entrepreneur would feel that his firm, acting alone, could not affect the world price of that commodity.

The quantity of output that can be produced in any period depends upon the quantity of inputs employed in the productive process and upon the present state of technology in the industry. This relation is expressed by a production function, which in its most general form is stated as

$$q = f(x_1, x_2, x_3, \ldots, x_n), \tag{2}$$

where q is the quantity of physical output and the x_i's are the quantities of physical input per unit of time. It is obviously assumed that within the relevant range an increase in the usage of any input increases output. In economic terminology we assume that the marginal products ($\Delta q/\Delta x_i$) of all inputs are positive. We also assume that if the usages of all other inputs remain constant and the usage of any one input increases, the marginal product of that input decreases but remains positive. We assume nothing about the way in which the marginal products of the input held constant change.

The production function is therefore a technical relation that shows the maximum amount of physical output for any given vector of inputs. We assume that this maximum output is unique.

Under these assumptions the present value of the firm's revenue can be stated as

$$(3) \quad P.V.\Pi = \sum_{t=0}^{H} \left(\frac{1}{1+r}\right)^t \{P_t f(x_{1t}, x_{2t}, \ldots, x_{nt}) - \sum_{i=1}^{n} P_{it}x_{it} - F_t\},$$

where x_{it} is the usage of the i-th input in the t-th period, P_{it} is the expected price of the relevant input, P_t is expected commodity price in the t-th period and F_t is the previously contracted fixed cost for that period.

It is simple to prove mathematically (as is done in Appendix B) that *maximization requires that for each period and for each factor of production the marginal product of that input in that period times expected commodity price (called the value of marginal product) equals the price of that input in that period.* This result is rather obvious. Assume that a particular type of input costs \$10 per unit per period of time. Assume an additional unit of the input would add seven units of the output and that the output sells for \$2 each. Thus an additional unit of the input would add \$14 to revenue per period of time at a cost of only \$10 per period, consequently adding \$4 to net revenue. Clearly the firm would add this unit and all other units that would add more than \$10 to revenue. Note, however, that if the firm continues hiring more and more of the input,by assumption marginal product would decline, and thus the value of marginal product would decline also. The firm would hire until the value of the marginal product per time period falls to \$10. It would not hire more, because the value of the marginal product would decline to less than \$10 per period and the firm would lose net revenue. Equilibrium, therefore, requires that

$$(4) \qquad P_t(MP)_{it} = P_{it} \text{ for } \begin{matrix} i = 1, 2, \ldots, n \\ t = 0, 1, \ldots, H. \end{matrix}$$

In our analysis of the mineral extracting firm and industry we are interested in large part in the comparative-statics impact upon total employment and total investment. To this end we simplify the general model somewhat. *First let us assume that there are only two factors of production necessary to produce output and let us call these inputs labor (L) and capital (K).* We take land, management, and other inputs as given for this problem. Admittedly this simplification leads to certain methodological complexities, foremost of which is the aggregation problem. It is difficult to conceive of adding together power shovels, drills, brooms, and so forth. Likewise there is the equally severe conceptual problem of adding secretaries, foremen, accountants, etc. But for both empirical and theoretical work this conceptual simplification offers great analytical convenience with little or no sacrifice of predictive power. *Lumping all types of labor into one group and all capital into another is particularly useful because we want to talk about the impact of policy changes upon employment and investment as a whole and not upon any one type of labor or any specific type of capital.* In theory we will abstract and assume some average or homogeneous grade of labor. Also we will assume that it is possible to measure and aggregate capital into homogeneous units. This method of approach is very frequently used in theoretical and empirical work, particularly in the aggregate models with which we will be dealing here.

We will assume that the mineral extracting firm attempts to maximize its present value, written as

$$(5) \qquad P.V.\Pi = \sum_{t=0}^{H} \left(\frac{1}{1+r}\right)^t \{P_t f(L_t, K_t) - W_t L_t - (r_t + d)K_t\},$$

where the variables are defined as follows:

L_t and K_t are the amounts of labor and capital used in the t-th period

H is the end of the firm's horizon, or the last period for which the firm makes plans

r is the interest rate - expected to remain constant

P_t is the commodity price expected in the t-th period; for simplicity we shall frequently assume that the firm expects price to remain at the same level over the planning horizon.

W_t is the expected wage rate in the t-th period; it is also frequently treated as a constant

d is the rate of depreciation of capital

In the profit function we assume that labor is hired each period at a specified wage rate parametrically given to the firm - and later to the industry. The treatment of capital is not so easily accounted for. Note that the firm in question owns no capital in this model. We assume that the firm hires its desired capital each period over the entire horizon. This assumption is more reasonable than it appears at first glance. Clearly the firm does not hire units of capital smoothly over its time horizon. It possibly buys most of its capital equipment early, and little capital late in its horizon. But, it uses capital rather smoothly over the time horizon, and if it borrows to buy the capital, it pays for the capital smoothly over the horizon. Of course the simplest interpretation might be that the entrepreneur or firm buys and owns physical units of capital, then rents these units to himself or itself at the going market rate. Models do exist in which the firm owns and uses a

stock of capital, but these models are quite complicated and would add little or no analytical fruitfulness to the problem at hand.[3]

Assuming an efficient capital market, the rate at which the firm can hire capital is precisely the interest rate plus the rate at which capital depreciates during one period. Thus if the firm hires $1000 worth of capital (of whatever sort it uses), it would pay $200 in a period if capital depreciates at a rate of ten per cent and the market rate of interest is ten per cent. We will assume in subsequent analysis that if the amount of capital hired during one or more periods rises after some policy change, we can assume that the rate of investment increases.

Adopting the above model to the changed assumptions, the firm attains equilibrium in any one period when

$$(6)\quad \begin{array}{l} \text{(a)}\ P_t MP_{L_t} = W_t \\ \text{(b)}\ P_t MP_{K_t} = (r+d) \end{array} \qquad t = 0, 1, 2, \ldots, H$$

where MP_{L_t} and MP_{K_t} are the marginal products of labor and capital in the t-th period.

Equations (6a) and (6b) show that in order to maximize profits, the firm must hire labor up to the point at which the addition to revenue produced by the last unit of labor equals the wage rate in each period. Likewise, the last unit of capital used in each period must produce an addition to revenue equal its cost to the firm in terms of interest and the rate of depreciation (r+d).

Therefore, from the conditions set forth in (6) the firm's demands for labor and capital can be expressed as functions of the parameters of the system: the wage rate, the price of output, the interest rate, and the rate of depreciation. In other words the demands are

$$(7)\quad \begin{array}{l} \text{(a)}\quad L_t = L_t(W_t, P_t, r, d) \\ \text{(b)}\quad K_t = K_t(W_t, P_t, r, d). \end{array}$$

It is quite a simple matter to show that from equation (7) the rate of change of labor and capital with respect to their own prices are negative. The signs with respect to other variables are not unambiguous. Finally, if L_t and K_t are determined by the parameters in equations (7), q_t is fixed by these parameters also.

Before extending the analysis to the mineral extracting industry we should examine the determinants of the horizon, H, for the mineral extracting firm. Mineral extraction presents a set of rather unusual circumstances, since an orebody is only augmentable to a limited extent. We assume that the firm owns or leases a specific deposit or area with minerals. The mined-out part of a deposit is not reproducable in each period. Furthermore, under no circumstances would all of the mineral deposit be extracted; at a point it becomes uneconomical to go further. We therefore set H in the following way. A geologist estimates the maximum quantity that can be extracted if in each period the output is recovered at the Maximum Efficient Rate (MER) of extraction, subject to the constraint that when profits become negative, extraction ceases. That is, the geologist maximizes

$$(8) \qquad Q = \sum_{t=0}^{\infty} \hat{q}_t$$

subject to

$$(9) \qquad P_t \hat{q}_t - C_t \geqq 0$$

for all t, where $\hat{q}_t$ is the MER of extraction, and Q is less than the total amount of the deposit. Clearly $\hat{q}_t$ need not be the most <u>economically</u> efficient rate - it is the most efficient rate from a purely technical

sense.

Clearly increases in expected prices or decreases in expected costs would increase Q by extending the horizon over which extraction would be economical. In our model we assume that H is determined by geologists but that it could change with new discoveries or with changes in parameters such as the price of the output. Also the cost of extraction will generally increase as the total deposit is decreased. Furthermore, production above the MER can under some circumstances increase costs and decrease Q, the maximum amount economically extractabl In our analysis of taxation and environment controls it will serve little purpose in including these modifications. Therefore, we will ignore them for now.

V-B.2. THE INDUSTRY

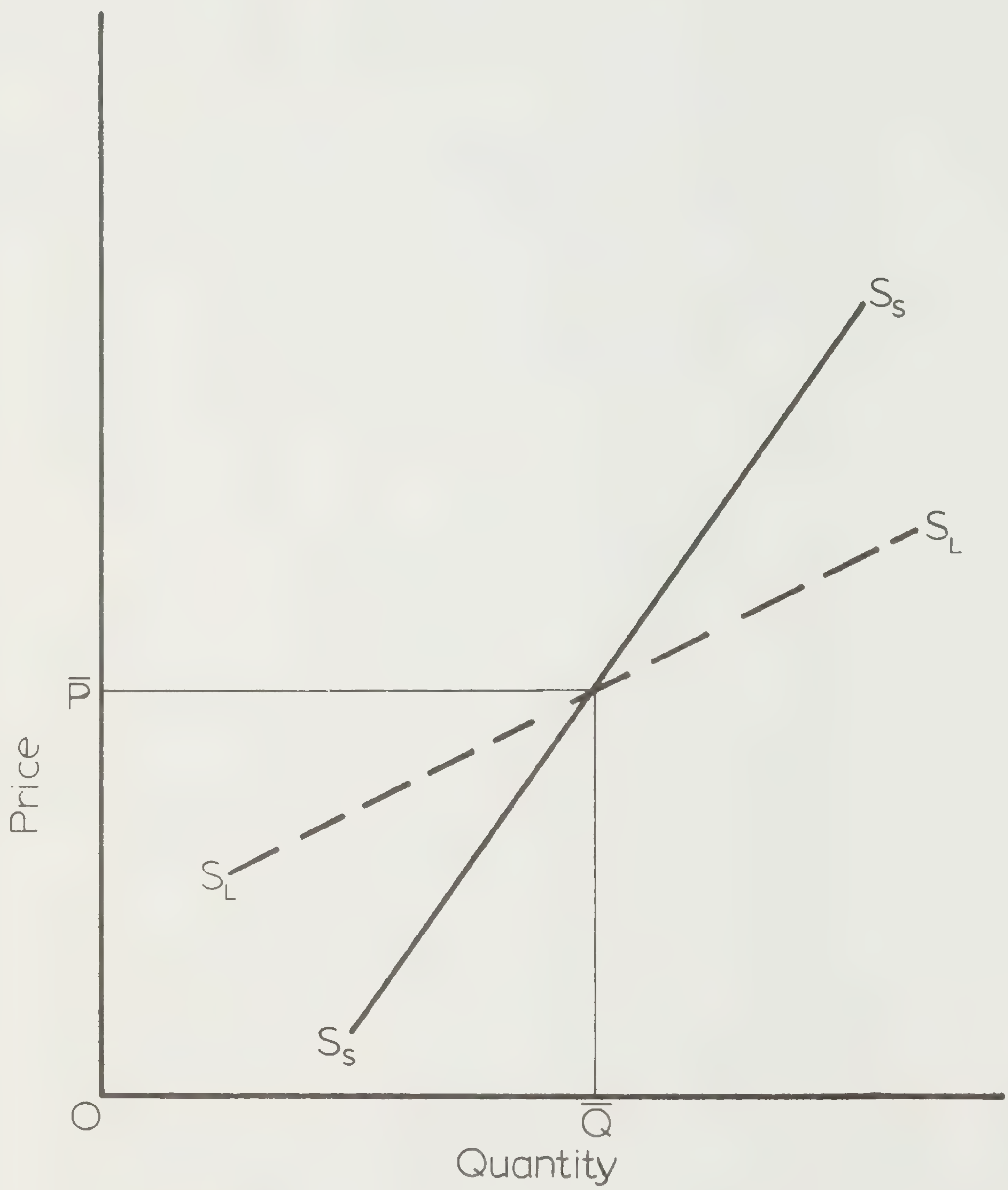
In most competitive models each firm in the industry faces a market-determined commodity price whereas the industry as a whole faces downward sloping demand for the product. In the short run industry supply is the summation of the individual supply curves of the firm. Price and output are determined where supply equals demand. In the long run firms enter the industry so long as commodity price is above the minimum average cost of the least efficient firms. Since the firm's cost is assumed to include the alternative or opportunity costs of resources owned by the entrepreneur, the marginal firms earn only the going rate of return on their resources; that is, there are no above-normal profits More efficient or lower cost firms earn above normal profits, but in the long run these profits may be received in the form of rents by the

owners of the factors of production responsible for the lower costs. These might be management or the owners of a particularly rich deposit. Of course, if all firms are alike, no firm earns above normal profit. In any case, price and output are still determined by this zero-profit, long-run supply and industry demand. The industry remains in equilibrium until something changes parametrically.

In the case of the mining industries of Ontario we will assume that the price of the mineral is determined on the world market and that the industry is a price taker in this market. In Chapter III we discussed the reasons for this assumption. The short-run supply curve is typically the sum of the suppliers of all firms already in the industry. The long-run supply curve allows for entry or exit by new firms or by old firms with new deposits. The least efficient firms cover only the alternative cost of their investment of other resources. The more efficient - for some reason or another - receive rents. *We might emphasize that no industry ever truly operates in the long run.* But since with free entry and exit, firms enter when the industry is profitable and exit when they cannot cover alternative costs, there is a tendency toward long-run equilibrium and this device is a convenient analytical fiction.

A theoretical mining industry - or, more accurately, a mining industry in a single province - is depicted in Figure 3. $\bar{P}$ is the price of the mineral, excluding transportation charges, given by the world market. $S_L S_L$ is the long-run industry supply curve drawn up under the assumption that entry or exit occurs until profit or losses are competed away for the less advantaged firms. There is no reason for exit of existing firms because all firms are covering the return obtainable at the next best alternative. There is no reason for entry because no firm

FIGURE 3 (CHAPTER V)



could get better than its alternative returns. $S_S S_S$ is short-run supply, drawn under the assumption that the number of firms remains constant. If price decreases or increases on the world market, adjustment at first would occur along $S_S S_S$.
Once firms have time to enter, in the case of profits, or exit, in the case of losses, $S_L S_L$ becomes the relevant supply. *Since firms are more flexible in the long run, the long-run supply is more elastic (less steep) than the short-run; that is, in the long run quantity supplied is more responsive to changes in price than in the short run.* Of course, once a new long-run equilibrium is reached, the number of firms changes and a new short-run supply obtained. The new short-run supply will intersect at the point where long-run supply intersects the new price.

This completes all the theory that we need to develop in order to analyse the impact of taxation and environmental controls. To be sure, a few modifications will be necessary, but these will be developed best within the context of the specific problem. In any case, the fundamentals of the theory set forth here are basic to the problems at hand. We may therefore proceed to the analysis of taxation.

FOOTNOTES - CHAPTER V

1. We ignore here certain other conditions that are set forth in the mathematical appendix.

2. The pattern of analysis that concerns patterns of adjustment is called dynamics.

3. In one such model the production function includes labor, current purchases of capital, and the present stock of capital. Capital lasts a specified number of years and depreciates at a specified rate. Thus in the t-th period output and cost depend upon the original stock of capital (if it had not all worn out), the current purchase of capital, the capital purchased in each period prior to the t-th and the rate at which capital depreciates. Or one can assume that capital wears out at a specific rate and is purchased at that rate. But it would be difficult to analyse investment responses to external changes within this context.

4. "Normal Profits" is a purely technical term in the theory of perfect competition. It is improper to apply it, with normative connotations, in political arguments over re-distribution of factor returns.

VI. ECONOMICS OF TAXATION

As noted in previous chapters, government imposes two major types of taxes upon the mineral extracting industries, a corporate profit tax and a mining tax upon the profits from the mining aspects of the firm. Both, therefore, are essentially profits taxes. In a straightforward static model the impact of these taxes is easily determined. Once dynamic implications are included, the impact is not so easily isolated. Neither is the effect upon the industry so easily analysed. We will begin analysis of taxation with the firm, then we will extend the analysis to the industry as a whole. We will then examine a slightly different static model of the firm. Finally we will consider the dynamic implications. Throughout we will attempt to determine the effect of changes in the tax rate upon total tax revenues.

VI-A. TAXATION AND THE FIRM

A profit tax of T_p, where T_p is between zero and one, simply reduces net profit to $(1-T_p)$ times gross profit in each period. The mining tax is a tax upon the profits earned on non-processed output. Let the mining tax be T_M, where $0 < T_M < 1$. First let profits, Π, be defined as profits in excess of the opportunity cost or alternative cost of the entrepreneur, which is the way that economists define profits.[1] Therefore, the firm would have in any period net profits after taxes of

(1) $$\Pi_n = (1-T_p)(1-\rho T_M)\Pi,$$

where ρ is the percentage of profit derived from mineral extraction.

Since gross profit depends upon output (commodity price is parametrically given) and output depends upon the quantities of labor and capital used, the firm choses the levels of labor and capital that maximize profits.
These maximizing levels are found by setting the partial derivatives equal to zero; thus, $\partial\Pi/\partial L = 0$, and $\partial\Pi/\partial K = 0$. With a profits tax and mining tax one differentiates net profit, Π_n, with respect to L and K to obtain

$$\frac{\partial\Pi_n}{\partial L} = (1-T_p)(1-\rho T_M)\frac{\partial\Pi}{\partial L} = 0 \tag{2}$$

$$\frac{\partial\Pi}{\partial K} = (1-T_p)(1-\rho T_M)\frac{\partial\Pi}{\partial K} = 0.$$

So long as corporate income taxes and mining taxes are less than one, the solution to (2) requires $\partial\Pi/\partial L = 0$ and $\partial\Pi/\partial K = 0$, the same solution as the profit maximizing solution when the tax rate is zero.

This result is obvious without resorting to the mathematical solution. If the tax rate on profit is T percent, the firm will continue to maximize the before-tax profits because it prefers (100-T) percent of maximum profits to (100-T) percent of some smaller level of profits. *Thus if $\hat{q}$, $\hat{L}$, and $\hat{K}$ are the optimal levels of output, labor, and capital with no taxation, they are also the optimal levels under any positive rate of taxation below 100 percent.* Within a model in which the entrepreneur's opportunity cost is not explicitly included no rate of taxation less than 100 percent would cause the firm to leave the industry. Any net profit above zero will induce the firm to

continue in the industry at the same level of output. *The arguments that taxation of profits at any level will disturb nothing are based upon arguments such as this. The argument continues that if no firm is affected the industry as a whole is not affected either.*

This situation is obviously not the way in which the firm operates. Assume for now that the cost function relevant to taxation does not include the entrepreneur's opportunity cost. In this instance the profit and the mining taxes are based upon profits as defined by the difference between total revenue and explicit factor costs, excluding opportunity costs. *Any tax on gross income that lowers the firm's discounted stream of gross profits below the opportunity cost would cause the firm in the long run to exit from the industry.*

Which firms will exit is an extremely tenuous question. One might say that those firms using the least productive deposits or perhaps those with the least efficient management would exit first, because these firms enjoy very little pure return even before the taxation. On the other hand, owners of the most efficient resources would have the highest opportunity costs, and these might be the first to seek out the best alternatives. Therefore, the question of which firms leave, if indeed any do leave, after an increase in taxation is probably empirical in nature for the general case. In the case of mineral extraction, however, returns over opportunity cost would probably depend largely upon the grade and accessibility of the deposits. Thus it may seem more likely that firms mining less productive deposits would close down operations in the long run. Those firms that are more productive because of high grade

continue to cover opportunity costs and hence continue to operate at the same level of output, employment, and investment as before. Again those that argue that taxation has little effect would point out that only the poorest marginal firms are affected; thus, taxation, which does not affect the intramarginal firms, has no effect on the more numerous efficient firms. Note, however, that analysis thus far has been based solely upon the static theory of the firm set forth above. We will modify these assumptions somewhat in the final portions of this chapter.

To summarize, a corporate income tax and a mining tax will leave the output, employment, and investment unchanged as long as the firm covers its opportunity cost. If it cannot do so, it will leave the industry. This conclusion is based upon very static assumptions, which will be modified below. Of course, a mining tax may change the firms' mix between mining and non-mining activities, but we will ignore this possibility here.[2]

VI-B. THE INDUSTRY

For analytical purposes we view the mineral industries of Ontario as the sums of the individual firms that comprise the sector. That is, we assume that no one industry is sufficiently large within the province to affect the average wage rate or the going rate of return to capital. Since most of the industries sell on the world market, we further assume, as noted above, that no single mining industry can, to any significant extent, affect the world price of its product.

Under thses assumptions the industry demand functions for labor and capital are

$$(3) \qquad L^* = \sum_{i=1}^{N} L_i \qquad K^* = \sum_{i=1}^{N} K_i$$

and the supply function is

$$(4) \qquad q^* = \sum_{i=1}^{N} q_i,$$

where L_i, K_i are the i-th firm's demands for labor and capital and q_i is the i-th firm's supply. N designates the number of firms in the industry.

While changes in the rates of taxation do not affect the input or output decisions of the individual firms, so long as opportunity costs are covered, they may affect both the output and usage of inputs in the industry. Obviously the reason these industry effects occur is because of the exit of some firms after a tax increase.

Under the assumption of the competitive model, any profits above opportunity costs induce entry into the industry. The entry of a new firm increases industry supply and lowers price. The price must fall until price equals average cost, which, of course, includes the entrepreneur's opportunity cost. Therefore, *in the long run there is no economic profit to be taxed.* Some firms may be more efficient than others, perhaps due to a favorable location or more efficient management, and therefore, have lower costs than other , less efficient firms in the industry. These firms

will find their costs rising, however, because of higher payments to the owners of those resources (possibly the deposits) responsible for the lower production costs.

Now assume that the income and mining tax is upon revenue less cost, and that cost does not include opportunity costs. The impact of the tax upon output, employment, and investment depends upon several key factors: (1) the effect upon commodity price, (2) the initial gross profit conditions of firms, (3) the generality of the tax, and (4) the ease of shifting resources.

Assume that mining firms vary in efficiency, because of varying resource productivity. The marginal firms earn approximately the marginal rates earned for similar investments in other industries. More efficient firms earn higher rates. *An increase in taxes will, therefore, cause the return for some firms to fall below what they could earn elsewhere. As they are able, these firms will exit, and the industry will move to a new equilibrium.* Since firms have fixed investments and contractual agreements, they cannot exit instantaneously. They will lay off workers, cut investment, and decrease output at a rate compatible with loss minimization. As firms exit from the industry, supply decreases, and of course investment and employment decrease also. The reason supply decreases is because the costs of individual firms rise after the taxes and because there are fewer firms.

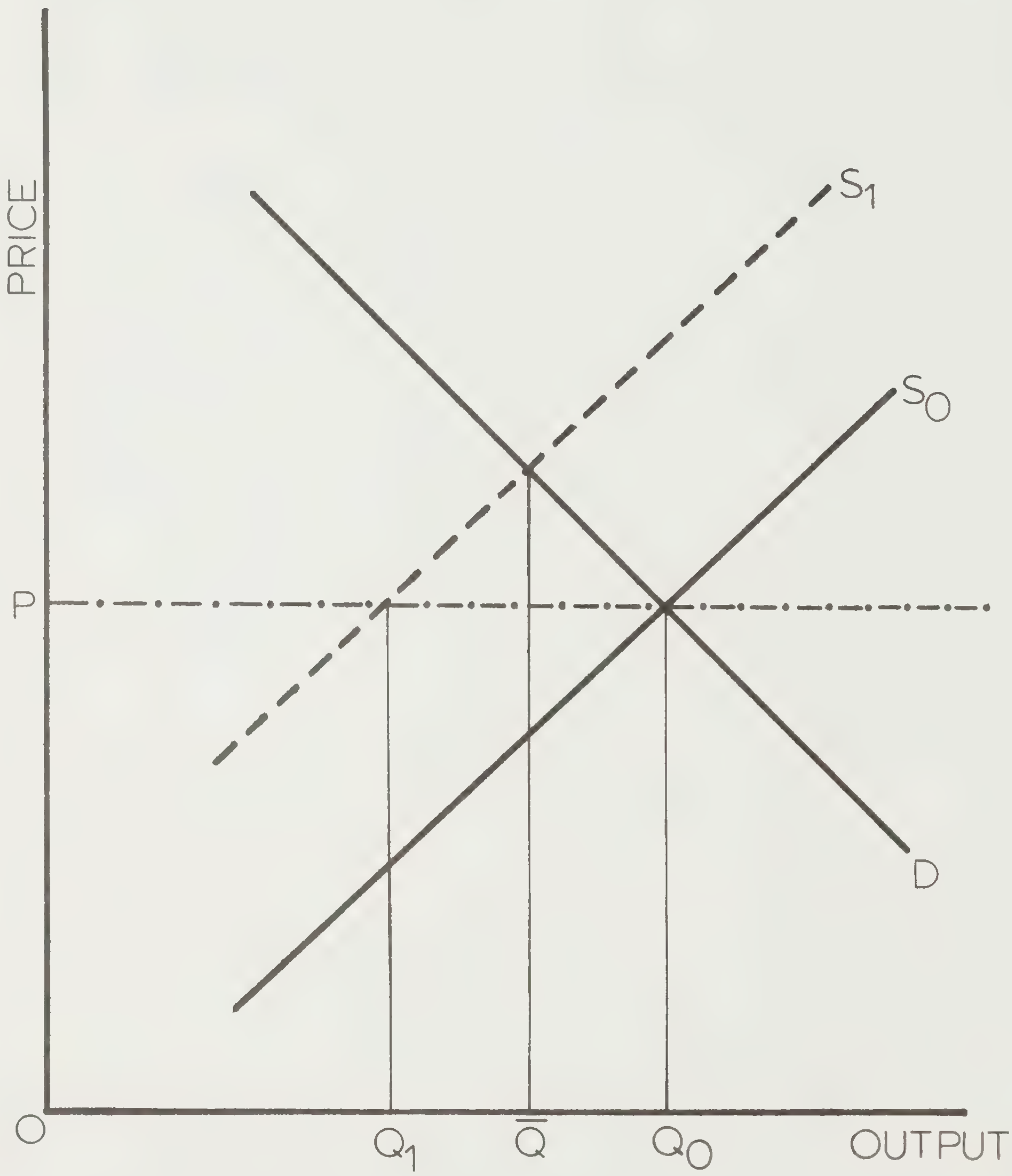
Mining firms have a significant additional possibility of reacting to tax increases - or for that matter to increases in other costs or to decreases in output price - by raising cut-off grade.

This enables them to avoid immediate exit or output reduction by reducing their ore reserves. Such practice is condemned by some as "high-grading" or resource wastage. However, all that is involved really is a trade-off between accelerated depreciation of one class of a firm's assets - conventional capital goods - and accelerated depreciation, or depletion, of another class of the same firm's assets - proven ore reserves.

If the industry makes up a significant portion of the market in which it sells its product, the price in that market will depend on the industry output. Some part of the tax will be passed on to the purchasers in the form of a higher price. This is shown in Figure 1. Assume the industry's supply is originally S_0. The intersection of S_0 with demand, D, gives a price of P and an output of Q_0. The imposition of a profit or mining tax that eliminates some firms by causing them to make losses decreases the supply curve of the industry say to S_1. If price could rise as supply decreases, more marginal firms would experience increased revenues to cover the increase in costs. In Figure 1 output would fall to $\bar{Q}$.

If, on the other hand, the industry sells on the world market, it has little, or at most a very small, effect upon the price at which it sells. This was the assumption for the mineral industries of Ontario. In this case the industry must absorb all of the tax increase rather than being able to pass some of it along. More firms are eliminated than would be the case when demand is downsloping, because higher prices would not cover higher costs.

FIGURE 1 (CHAPTER VI)



Obviously employment and investment would decrease more also under the assumption of a given commodity price than under a downsloping demand. In terms of Figure 1, output would fall to Q_1 rather than $\bar{Q}$. *THUS IF THE POLICY IS TO REDUCE OUTPUT, EMPLOYMENT, AND INVESTMENT AS LITTLE AS POSSIBLE, THE WORST TYPE OF INDUSTRY TO TAX IS ONE THAT MUST TAKE A WORLD COMMODITY PRICE AS GIVEN. In this case none of the tax could be shifted to buyers.*

Certainly the initial profit position of firms in the industry determines the ability of the industry to absorb the tax burden. *In the extreme case in which all firms are earning no profits above the rate on alternative investments, any increase in the tax rate in the long run eliminates the industry, when commodity price is parametrically given.* That is, no firm can cover opportunity costs. This, of course, assumes that a proportional tax is not placed upon all other industries and the alternatives consequently lowered. *At the other extreme in which all firms are earning profits well above the alternatives due to superior deposits or other resources, the tax increase simply lowers the net return, and employment, investment, and output remain unchanged.* Only a thorough study of the relevant industries themselves can give insight into the relative position of those industries.

Therefore, to summarize, the industry's demand functions for labor and capital are

(5) (a) $L_t^* = L_t^* \ (W_t, P_t, r, d, T_p, \rho, T_m)$

(b) $K_t^* = K_t^* \ (W_t, P_t, r, d, T_p, \rho, T_m)$

and the industry supply function for output is

(6) $q^* = q^* \ (W_t, P_t, r, d, T_p, \rho, T_m)$

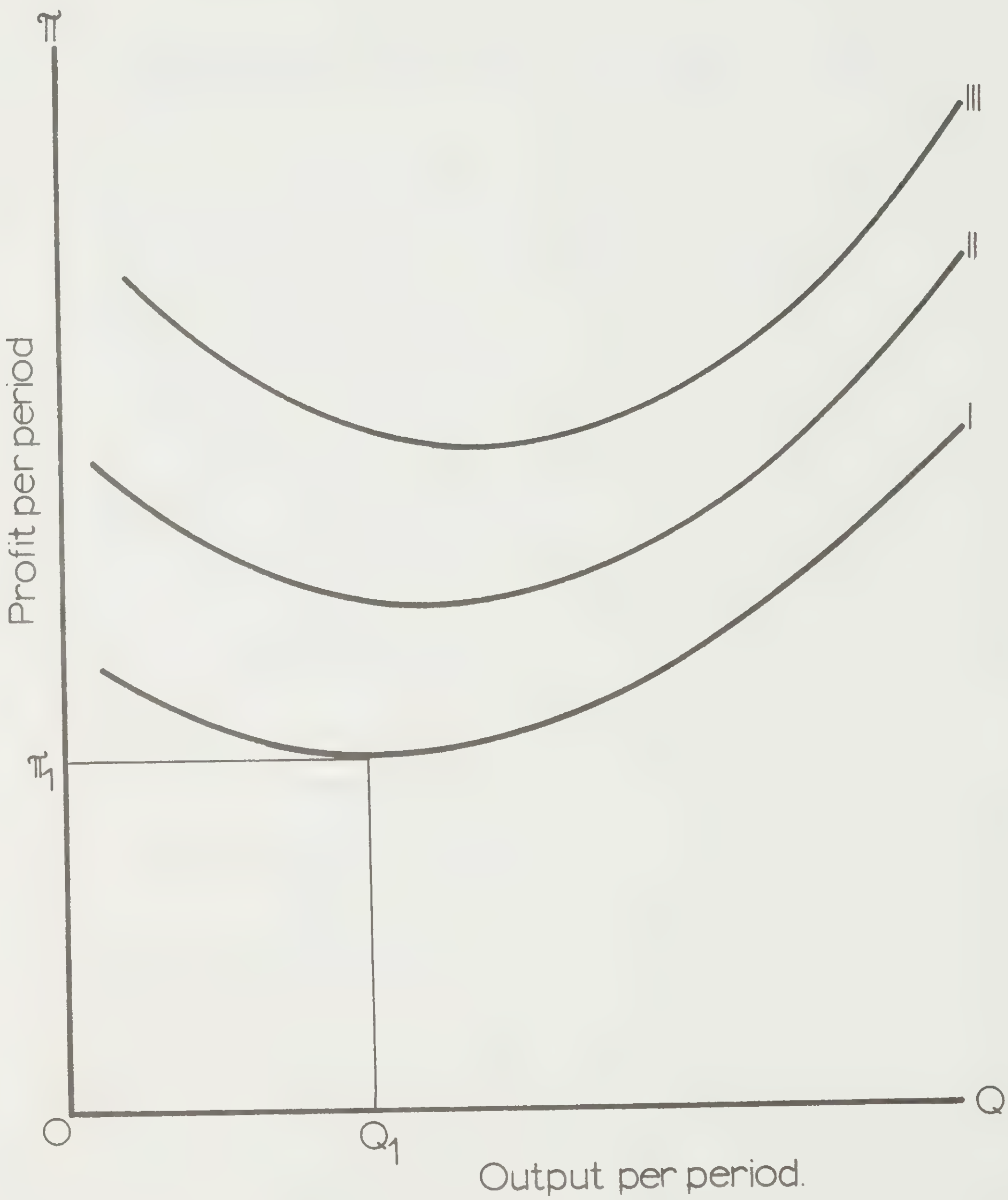
Increases in T_p, T_m, and ρ, would under most circumstances lower q^*, L^*, and K^* for an industry as a whole. This about exhausts what we can do with the usual static model of the firm and industry. The magnitude of the impact on the variables in question must

depend upon the particular characteristics of the industry in question. Let us now turn to some alternative methods of approach.

VI-C. PROFIT AND THE SUPPLY OF ENTERPRISE

Until now we have assumed that entrepreneurs were interested solely in the magnitude of profit. We can, however, employ a slightly different approach and assume that entrepreneurs or owners of firms are willing to trade off their entrepreneurial services for profits at a particular rate.[3] That is, increased output requires increased entrepreneurial services, and the entrepreneur is willing to trade his entrepreneurial services for profit. A "typical" entrepreneur might have trade-off rates as depicted in Figure 2. In Figure 2 the curves labeled I, II, and III are an entrepreneur's indifference curves between profit (plotted on the vertical axis) and output (plotted on the horizontal axis). It is assumed that increased output requires entrepreneurial services. An indifference curve shows all combinations of profit and entrepreneurial services among which the entrepreneur is indifferent; that is, all combinations of Π and Q depicted by indifference curve I yield the same level of utility or satisfaction. All combinations on higher indifference curves yield a higher level of utility. All combinations on II are preferred to all combinations on I, and combinations on III are preferred to those on II, and so forth. I, II, and III are only three of the infinite number of conceivable indifference curves.

FIGURE 2 (CHAPTER VI)

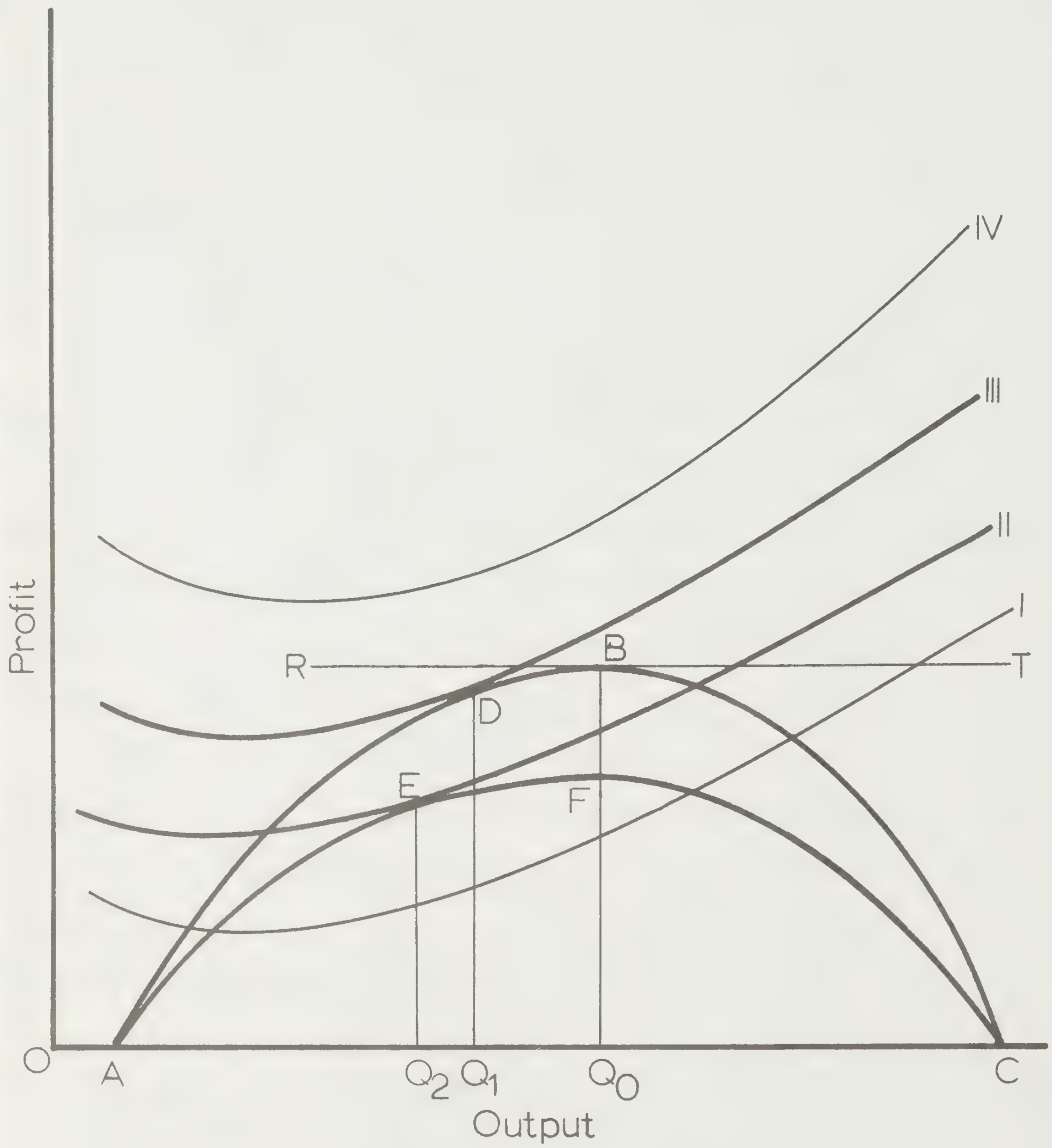


Since every Π-Q combination in the quadrant is possible, the curves are everywhere dense.

The slope of the indifference curves show the rate at which the entrepreneur is willing to trade off profit for additional entrepreneurial services. The curves are drawn first with a downward slope. This may reflect that the size of the enterprise - and therefore the amount of services required - is so important that the entrepreneur is willing to sacrifice profits for increased sales. Beyond a certain point, such as an output of Q_1, with a profit of Π_1, on indifference curve I, the entrepreneur is willing to expend additional services and increase output only if he is rewarded with increased profit. The curves also are drawn to reflect that the rate of substitution decreases at a decreasing rate then increases at an increasing rate. The domain of output or services over which the indifference curves decline is determined by the importance of sheer size of the firm to the entrepreneur. For the "captains of industry" this domain may be extensive.

While indifference curves show the rate at which entrepreneurs are willing to trade profits for entrepreneurial services (output), they do not indicate how the market and technological forces affect the trade off. Assume that profit, the difference between revenues and factor costs before taxes, is given for each level of output by the curve ADBC in Figure 3. This is the rate at which the market allows profits. Maximum profit, Q_0B, occurs at the level of output OQ_0. Any higher (lower) level of output requires more (less) entrepreneurial service and is associated with a lower level

FIGURE 3 (CHAPTER VI)



of profit. Indifference curves I-IV are from the entrepreneur's family of indifference curves. IV and all other curves above III lie everywhere above the profit-possibility locus ADBC. II, I, and all curves below III lie partly within the attainable region, but they yield lower levels of utility than III. Thus utility level III is the highest attainable, and this level is possible only at output OQ_1, yielding profit Q_1D. Only if indifference curves are horizontal over the relevant range will the maximum profit level be chosen; for example the indifference curve RT is tangent at B. Horizontal indifference curves indicate that the entrepreneur neither increases nor decreases his level of utility from additional output and personal services.

Let us return to the case in which the entrepreneur chooses OQ_1 and profit of Q_1D. Impose a proportional tax on profits that lowers the profit-possibility curve to AEFC. In the example depicted the highest level of utility, given now by indifference curve II, is attained at OQ_2 and a profit of Q_2E. The III-level and all levels above II are now unattainable. In this case, as opposed to the profit - maximizing case, output, and therefore employment and investment, are reduced. Of course, the curves could have been drawn such that output might increase from OQ_1, or even remain constant.[4] The only case, however, in which output would <u>necessarily</u> remain constant is the case of perfectly horizontal indifference curves. Then output would remain constant at OQ_0 regardless of the tax and profit would fall to Q_0F for the tax depicted. This describes the model of the firm set forth in the preceeding subsections.

This analysis is not meant to show that a profit tax necessarily decreases output. It is only to indicate that if the supply of entrepreneurial services is positively sloped - and there is good reason to believe that it often is (see footnote 3) - there is a strong theoretical possibility that an increase in the tax on profits will lower a firm's output, employment, and investment, even though the firm covers its opportunity cost both before and after the tax increase. This result could not be deduced from the previous model.[5]

VI-D. SOME DYNAMIC EFFECTS

Thus far in our analysis of the effects of taxation we have assumed that entrepreneurs somehow know what will happen in the future, that they know exactly what to do, that they can easily and automatically adapt to changes in the environment. Obviously, this is not the real-world situation. Even though the model in which the firm exists in a world of certainty is a useful analytical device, capable of answering many complex economic problems, for a complete analysis one must generally adapt some of the assumptions in order to obtain a more realistic picture of the firm in a dynamic environment. We now extend the analysis in that direction.

Consider why mineral firms carry out an investment, explore for new deposits, expand their scope of operation. Obviously, firms continue to invest in new capital, to search for new deposits, and to expand as long as the last unit of investment, of search, and so forth is expected to add more to the firm's net income than the cost to the firm. *An increase in the rate of taxation does not change the probability of*

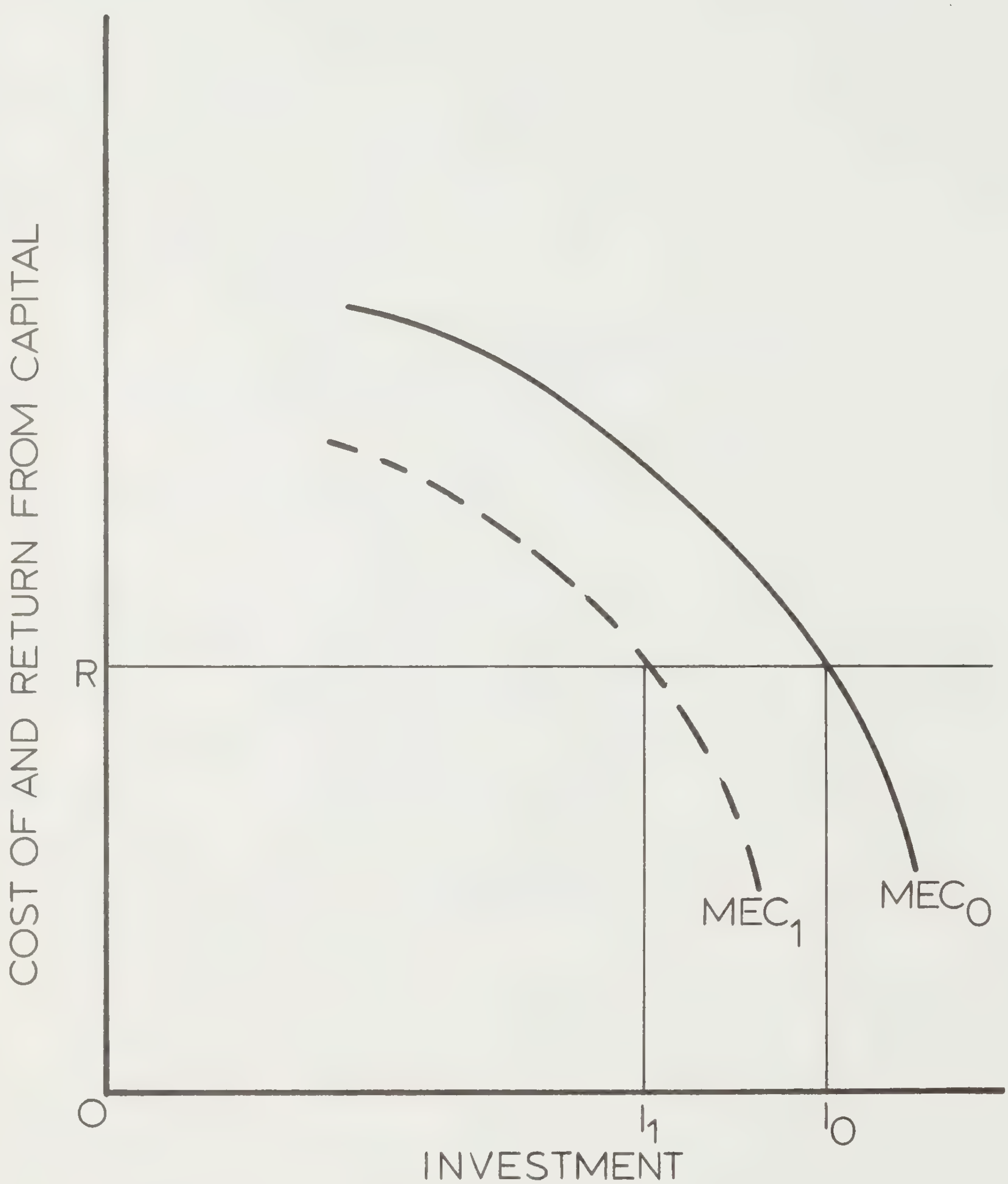
success. It does, however, reduce the stream of profits expected from a new venture or a new investment.

This effect of a profits tax is particularly severe in the case of new firms or in the case of an old firm undertaking expansion or innovation. The new firm knows that there will be a lean period in the beginning, a period during which profits will be zero or even negative. Obviously, the entrepreneur will begin the firm or carry out the innovation if discounted distant profits are expected to exceed current losses. Anything that lowers the expected profit stream will at the margin discourage present innovation and investment. The decision to undertake research and development is based upon the same premise.

Figure 4 illustrates the point rather clearly in the case of investment.

The Marginal Efficiency of Capital (MEC) is defined as the additional expected return from an incremental unit of investment. The expected marginal return varies inversely with the amount of investment, reflecting that the best (most profitable) investments are undertaken first. The firm would undertake investments as long as the expected marginal return exceeds the cost of the additional investment. If MEC_0 in Figure 4 shows the expected marginal return facing a firm and R is the cost of an additional unit of investment, the firm would invest I_0 in the relevant time period. *A tax on profit would lower the MEC schedule,* in Figure 3 from MEC_0 to MEC_1. In this case investment would fall to I_1. *The extent of the decline in MEC depends of course on the magnitude of the tax. In addition the MEC will decline if managers anticipate further increases in the rate of taxation.*

FIGURE 4 (CHAPTER VI)



One might logically apply the same type of analysis to mineral exploration, research and development, and innovation. The firm undertakes these types of expenditures only so long as the expected value of the research, exploration, etc. exceeds the cost. Anything, such as increased taxation, must reduce this type of expenditure.

An additional implication of taxation can be deduced from the principle of increasing risk. Thus far we have emphasized that increased taxation strongly affects the smaller firms and the less profitable firms. In some instances one can present a convincing case that the marginal effect of taxation upon investment and so forth, increases with the size of the investment. The reference cited in footnote 3 above showed an interesting example of this point; it pointed out that if a firm expands its scale of operation with borrowed capital, the greater the proportion of borrowed capital to its own equity, the greater the risk of loss of equity. As an example, it compared two firms. If a firm with $100,000 owned capital and $100,000 borrowed capital suffers a loss of five percent, this is a loss of ten percent to the firm. Another firm with $100,000 plus $900,000 borrowed capital suffers a fifty percent net loss from a net loss from a five percent loss on the total. The above reference concluded that an expansion of output with exactly the same actuarial value of profit will be more attractive at small outputs than large. The larger the planned increase in output, other things remaining the same, the greater must be the expectation of profit to induce further expansion. For this reason *taxation that lowers the expectation*

of profit tends to become progressively inhibitive upon investment, exploration, and research.

Finally, we should mention the psychological impact upon the general attitude of entrepreneurs. In a world of uncertainty about the future this business attitude becomes increasingly important. In this case one must make the economic distinction between the manager, who continues managing the firm in traditional ways and taking it in traditional directions, and the entrepreneur, who carries out innovations and changes the typical methods of production and of doing business.[6] The manager, who operates routinely, making routine decisions, has some strong ideas about the probability of failure or success in particular ventures. The entrepreneur, who introduces innovations ,who makes radical changes, typically has little idea of the true probability of success. He frequently has a feeling for a project; he simply believes that some new previously unknown method of production or maketing will be profitable. In this sense, the entrepreneur's general attitude about the future becomes of primary importance . Often some small external change can alter the business attitude from optimism toward pessimism. *To the extent then that taxation dampens the attitude of entrepreneurs toward the future, investment, expansion, and innovation will be dampened also.*

To summarize, we must conclude that, theoretically, only in one special case will an increase in the rate of taxation have absolutely no impact upon output, investment, employment, innovation, exploration, and R & D. This is the case of the

competitive industry in which all firms are earning sufficient profits above alternative or opportunity costs that the tax does not reduce any profits below what could be earned elsewhere. Furthermore, the supply of entrepreneurial services must be perfectly horizontal, dynamical considerations must be absolutely neutral, and the expected stream of profit must continue sufficiently large so that long-term investment and innovation are not diminished. These must be the assumptions from which one argues that taxation leads to no diminution of output, etc., in the long run.

Otherwise taxation has negative effects. First, firms that cannot cover their alternative costs leave the industry, thereby decreasing output, employment, and investment directly. This effect was shown to be particularly severe for an industry that is a price taker in the world market. The anticipated return from investment and exploration for surviving firms and prospective new entrants is decreased, thereby lowering output, employment, and investment in the future.

This analysis about exhausts the theoretical impact of profit and mining taxes. Note that once we go beyond the static analysis, we do not argue that every firm or every entrepreneur will be similarly affected. Some may be affected, some may not. We only wish to show that some adverse effects are possible, even probable. It is the <u>marginal</u> impact in which we are interested. If enough firms are somewhat affected these marginal effects can be significant indeed. Thus the magnitude of the impact on the variables in question must depend upon the particular characteristics

of the industry in question. Further analysis in this area is, therefore, an empirical question. Much further research into individual industries will be necessary to determine more precisely the impact in specific instances.

VI-E. EFFECT UPON TAX REVENUES

If the mining or the corporate tax is increased, the effect upon the tax revenues of the government are three-fold. This can best be seen with the use of an equation. If $\bar{T}$ is the average rate of taxation ($0 < \bar{T} < 1$), Π is the average rate of profit in the industry, and N is the number of firms in the industry the total revenue from a tax is

$$R = \bar{T}N\Pi. \tag{7}$$

A slight change in the rate of taxation changes revenue in approximatel the following way:

$$\frac{\Delta R}{\Delta T} = N\Pi \frac{\Delta \bar{T}}{\Delta T} + \bar{T}\Pi \frac{\Delta N}{\Delta T} + \bar{T}N \frac{\Delta \Pi}{\Delta T} . \tag{8}$$

The first term of (8) is the additional amount of tax revenue if the total level of industry profit remained the same after the average tax rate rises. If taxes increase 10% for example ($\frac{\Delta T}{\Delta T} = .1$ and initial industry profits are \$100 million, $N\Pi \frac{\Delta T}{\Delta T}$ = \$10 million. Frequently in analysis only this term is considered while the impact of the second and third terms are disregarded. As noted above, however, these latter terms may be significant.

The second term of (8), $\bar{T}\Pi\frac{\Delta N}{\Delta T}$, is the effect that a fall in the

number of firms caused by the tax increase has on tax collection. Clearly if the tax rate rises, marginal firms leave the industry, $(\frac{\Delta N}{\Delta T}) < 0$. The third term of (8), $\overline{T}N\ (\frac{\Delta \Pi}{\Delta T})$ is the effect that the tax rate increase has on the profit rate of the average firm. $(\frac{\Delta \Pi}{\Delta T})$ will be negative and its absolute value will be larger the smaller the control the firm and industry exercise over price. For an industry engaged in international sales such as the Ontario mining industry we would expect the absolute value of $\frac{\Delta N}{\Delta T}$ and $\frac{\Delta \Pi}{\Delta T}$ to be large relative to an industry which sells its product solely on the domestic market. Therefore *the effect of taxes on the employment, investment, and output decisions of the mining industry would be expected to be larger than for industries which largely sell in the domestic market.* These firms could perhaps shift some of the tax to consumers in the form of higher prices whereas a world price taker cannot.

Needless to say, it is certainly conceivable that the second two terms, both of which are negative, could overwhelm the first term, which of course is positive. The actual impact upon tax revenues is therefore an empirical question. One would have to investigate the profit situation in specific industries to forecast the effect of tax changes in particular cases. This is about as far as it is possible to go theoretically in this area; however, much further empirical work is needed.

FOOTNOTES CHAPTER VI

1. Recall from Chapter V that the opportunity cost to the entrepreneur is the return that could be obtained if the entrepreneur used his own resources - including his labor - in their next best alternative use. We will here, as we do throughout, abstract away from the entrepreneur's preferences for specific industries and assume that they will go to the highest return if given sufficient time of adjustment.

2. One might suppose that a localized mining tax would switch some resources away from the area that imposed the tax toward areas with lower or no local taxation. This possibility is taken into consideration by the opportunity cost. For firms mining in Province A, the relevant opportunity cost might be mining in Province B. If A imposes a localized mining tax firms will leave if they cannot cover opportunity costs. The situation, therefore, fits that set forth in the body of the text.

3. The remainder of this section is based upon K.E. Boulding, "The Incidence of a Profits Tax," The American Economic Review, Sept. 1945, pp. 567-572. Subsequent papers have followed Boulding's approach.

4. There is another possibility. The desire for size, the captain-of-industry effect, may be so great that the indifference curves slope downward over such a long range that tangency occurs at an output greater than OQ_Q. The effect of a profit tax in this situation is ambiguous.

5. For a rigorous but non-mathematical and simple exposition of indifference curve theory and the theory of the competive firm and industry see C.E. Ferguson and S.C. Maurice, Economic Analysis, revised edition (Richard D. Irwin and Co., Homewood, Illinois, 1974). For a more rigorous but more complicated exposition see C.E. Ferguson, Microeconomic Theory, third edition (Richard D. Irwin and Co., Homewood, Illinois, 1973). For indifference curve theory see Chapters 3 and 4 of the former and 2 and 3 of the latter. For the theory of the competitive firm see Chapters 8 to 11 of the former and 8, 13, and 14 of the latter.

6. It is important to emphasize that the businessman may carry out the functions of a manager a large part of the time and also those of the entrepreneur some of the time.

VII. ECONOMICS OF ENVIRONMENTAL CONTROLS

One must use a somewhat different methodology from that used to analyse taxation when dealing with the problems of environmental controls. Since the controls are essentially constraints upon the firm, the problem is one of constrained maximization. Thus the derivation of the results is largely mathematical in nature, and the mathematics are more complex than those used to analyse taxation. As before all mathematical derivations are confined to the Appendix (D). In the body of the chapter we set forth the assumptions and exposit the economic implications of the conclusions. First we discuss the problems involved. Then we discuss the economic impact of different types of environmental controls upon individual firms. Finally, we analyse the impact upon entire industries. Some of the conclusions are not at all intuitively obvious; in fact, some conclusions are rather unexpected.

VII-A. TYPES OF CONTROLS

In effect, almost all environmental controls are in the form of externally imposed constraints placed upon firms. Governmental reasoning for the justification of these constraints takes the following form. *A competitive industry produces an output such that the marginal cost to the firm equals the marginal social benefits to society.* The benefits are measured by price; that is, the amount society is willing to pay. *If a firm or industry pollutes the environment, it is argued, society as a whole bears some of the costs. Since the firm is interested solely in private costs, it ignores in its output calculations these social costs.*

They are therefore passed on to society in the form of pollution and output is not optimal in the sense that total marginal cost exceeds total marginal benefit. Environmental controls are one method, but not the only method, used by society to force the firm to reduce the social costs or turn them into private costs. We might note parenthetically that if consumers are concerned enough, buyer pressures or boycotts resulting in lost sales may in some instances force the firms to absorb some or all of these social costs. We will ignore this aspect of the problem, however; since the mining industries of concern sell in a world market, passing over this aspect of the problem seems justified.

In the case of mining, environmental constraints generally take five forms. First, the government limits the amount of some by-product of the firm's output that the firm can put into its external environment per time period. Such emission controls may be upon smoke, sulphur dioxide, or other gases released into the air or upon solids or upon reagents from tailings dams into flowing water. Control of acid mine water discharge into streams, which is not a great problem in Ontario, though of considerable importance in some mining districts in the United States, also comes under this heading. Second, such controls may be expressed in terms of limits of total pollutant content that may be present in firms' external environment. Such ambient controls, though apparently similar to emission controls are economically quite different as any single firm's action immediately affects the constraints for all others. Externalities or property right

problems emerge. Third, emission or ambient controls may be imposed upon a firm's internal environment. The distinction here ceases to be relevant as the cost of operating capital equipment <u>within</u> one firm is raised. Under this heading would come dust or noise controls on some heavy machinery. Fourth, reclamation of land surface used by the firm during production may be required at the end of that firm's life. Fifth, a bond to pay for such reclamation may be required to be posted at the beginning of a firm's operations.

For analytical convenience and simplicity let us group the five types of constraints into three. First consider the constraint upon the amount of pollution that can be emitted per time period.

In all such cases the restriction is in the form of a constraint upon the profit maximizing firm. To summarize the problem, any increase in output increases the firm's sales revenue and also increases costs of production because of the increased usage of labor and capital. But, the increased output also adds to pollution. If the firm is limited in the amount of pollution in each period, after a point it must use resources, labor and capital, to eliminate the additional pollution. This additional labor and capital also adds to the marginal cost of the increased output. Therefore, if the restriction is relevant (that is, the firm would, if permitted, pollute more than is allowed), the total marginal cost of producing more output must rise. One would think that obviously the restriction would reduce output, and reduce the usage of labor and capital. This does not necessarily follow from

the theory. We will discuss the implications in the next section.

The second general type of environmental restriction is the requirement that the environment must be restored to some designated level after production has ceased. In this case labor and capital are used to reduce pollution after production has ceased. The results of changes in this type of restriction are shown to be quite similar to those described above. The effects of the third general type of constraint, pollution standards upon capital equipment, are simply derived. This restriction merely raises the cost of using capital. The results are like those that follow from raising the price of any factor of production. The effect of this type is described briefly in the text. We now turn to an analysis of the effects of these constraints upon mining firms.

VII-B. ENVIRONMENT CONTROLS AND THE FIRM

Assume the typical firm that we set up in Chapter V and assume that there is a constraint imposed upon the amount of pollution that the firm can emit during any time period. Again in each period the firm hires labor and capital at rates w and (r+d) respectively. Both labor and capital can be used in two ways, to produce output and to reduce the pollution resulting from production. Let L_t^0 and K_t^0 designate the amounts of labor and capital used to produce output during the t-th period. Thus, the production function is $q_t = f\ (L_t^0, K_t^0)$, where both marginal products are positive. Also let L_t^1 and K_t^1 designate the amounts of labor and capital used in the t-th period to reduce pollution. The total amounts of labor hired,

and capital leased are L_t and K_t; thus $L_t^0 + L_t^1 = L_t$ and $K_t^0 + K_t^1 = K_t$. Assume the amount of pollution released in any one period, written as η_t, depends upon output, q_t, in the following way:

(1) $$\eta_t = h(q_t),$$

$$\frac{\Delta\eta_t}{\Delta q_t} > 0.$$

The "production function" for pollution reduction is

(2) $$\eta_t = \phi(L_t^1, K_t^1),$$

where

(3) $$\frac{\Delta\eta_t}{\Delta L_t^1} < 0 \text{ and } \frac{\Delta\eta_t}{\Delta K_t^1} < 0.$$

If the government forbids the firm to emit more than $\bar{\eta}_t$ into the environment during the t-th period, the firm's constraint is

(4) $$\bar{\eta}_t - h[f(L_t^0, K_t^0)] - \phi(L_t^1, K_t^1) = 0.$$

That is, the firm may pollute in a period until $\bar{\eta}_t$ is reached. Beyond this level the pollution emitted by using additional L_t^0 and K_t^0 must be eliminated by using additional L_t^1 and K_t^1. Thus the total cost of producing beyond the point at which $\bar{\eta}_t$ is reached is the cost of the inputs used to produce output plus the cost of inputs used to reduce pollution. We assume that the restriction is severe enough that the firm would pollute more than $\bar{\eta}_t$, if it were free to do so. If the constraint would not be met, the

problem is trivial - the constraint has no effect. We also assume that the profit maximizing assumption limits the firm to meeting the constraint by reducing pollution no more than is required by the constraint. Thus, the equality sign holds.

The firm maximizes its present value, written as

$$\text{(5)} \qquad PV = \sum_{t=0}^{H} \left(\frac{1}{1+r}\right)^t \{P_t f(L_t^0, K_t^0) - wL_t - (r+d)K_t\},$$

subject to

$$\text{(4)} \qquad \bar{\eta}_t - h[f_t(L_t^0, K_t^0)] - \phi[L_t^1, K_t^1] = 0.$$

It is logical to assume that a reduction in the constraint would lower profits and an increase in the amount of pollution allowed would increase profits.

The firm has four choice variables during any period of time: L_t^0, L_t^1, K_t^0, and K_t^1. The maximization of present value requires that for all t

$$\text{(7)} \qquad \bar{\eta}_t - h(q_t) - \phi(L_t^1, K_t^1) = 0$$

$$\text{(8)} \qquad P_t(MP)_{L_t^0} - \lambda \frac{\Delta\eta_t}{\Delta q_t} (MP)_{L_t^0} = w$$

$$\text{(9)} \qquad P_t(MP)_{K_t^0} - \lambda \frac{\Delta\eta_t}{\Delta q_t} (MP)_{K_t^0} = (r+d)$$

$$\text{(10)} \qquad -\lambda(MP)_{L_t^1} = w$$

$$\text{(11)} \qquad -\lambda(MP)_{K_t^1} = (r+d)$$

where the previously undefined terms in equations (7) - (11) are defined as follows:

$(MP)^0_{L_t}$ and $(MP)^0_{K_t}$ are the marginal products of labor and capital in terms of output; both are positive.

$(MP)^1_{L_t}$ and $(MP)^1_{K_t}$ are the marginal products of labor and capital in terms of reducing pollution; since it is assumed that labor and capital can reduce pollution, these terms are negative.

λ, a factor of proportionality, is the shadow price of a change in the pollution constraint; i.e., λ is the ratio of the change in present value of the firm to a change in the amount of pollution allowed per period, or $\lambda = \Delta[\Sigma(1/1+r)^t \Pi_t]/\Delta\bar{\eta}_t$. Since an increase in the permissible pollution, $\bar{\eta}_t$, increases profits, λ is positive.

For convenience we shall drop the "t" notation in the subsequent discussion.

First equation (7) simply states that in equilibrium the constraint must be met. The other results do not follow so trivially. Equations (8) and (9) show that the firm will use labor and capital to produce output until the <u>full</u> values of their respective marginal products are equal to their respective wage rates. In this case, as opposed to the non-constrained cases set forth in previous chapters, the value of the marginal product is not the price of the commodity times the marginal product of the input. The value of the marginal product is lower in the constrained case. The difference lies in the total effect of changing either

L^0 or K^0. When pollution is restricted, a unit of input adds the commodity price times the marginal product to revenue, but the marginal product (or increased output) resulting from the increase in the input also adds to pollution at the rate $\Delta\eta/\Delta q$, which is positive, and additional pollution above the constraint decreases profit at the rate λ. Therefore, the total values of additional labor and capital are $(P - \lambda\Delta\eta/\Delta q)(MP)_L 0$ and $(P - \lambda\Delta\eta/\Delta q)(MP)_K 0$. This is what we meant in section VII-A above when we implied that a constraint could change a social cost that is not a private cost into a pure private cost. Thus a constraint can to some extent internalize an externality. Since the wage rate, the return to capital, and the rate of depreciation are parametrically given, a reduced net return to both inputs after a constraint would seem to imply a reduced usage of both inputs. From this model, however, this last implication need not hold.

Equations (10) and (11) show that the firm will use labor and capital to reduce pollution until values of marginal products in these uses equal respective rates of return. The value of an input's marginal product is the shadow price of an additional unit of pollution times the rate at which that input reduces pollution. We might note that the assumption of $\Delta\eta/\Delta L^1 < 0$ and $\Delta\eta/\Delta K^1 < 0$ (i.e., that marginal products in reducing pollution are negative) along with positive rates of return imply in equations (10) and (11) that the shadow price, λ, is positive, a conclusion that has been until here merely asserted.

We might note in passing that equations (8) and (10) imply

that in equilibrium

$$\frac{(MP)_L 0}{(MP)_L 1} = - \frac{\lambda}{P-\lambda\frac{\Delta\eta}{\Delta q}}, \tag{12}$$

and equations (9) and (11) imply that

$$\frac{(MP)_K 0}{(MP)_K 1} = - \frac{\lambda}{P-\lambda\frac{\Delta\eta}{\Delta q}}, \tag{13}$$

which in turn implies that

$$\frac{(MP)_L 0}{(MP)_K 0} = \frac{(MP)_L 1}{(MP)_K 1}. \tag{14}$$

Thus the firm allocates a given amount of labor until the ratio of the marginal products in each occupation, producing output and reducing pollution, equals the ratio of the returns in each occupation. The same thing applies to capital. From (14) the ratio of the marginal product of labor to the marginal product of capital is the same for either occupation.

We have deduced that changing from no constraint to some positive finite constraint may decrease the usage of labor and capital used to produce output and increases the amount of each used to reduce pollution (obviously, none of either was used in the latter occupation prior to the constraint). Which effect prevails cannot be deduced from the model thus far, and so we cannot deduce here the net effect of imposing a constraint upon employment or investment.

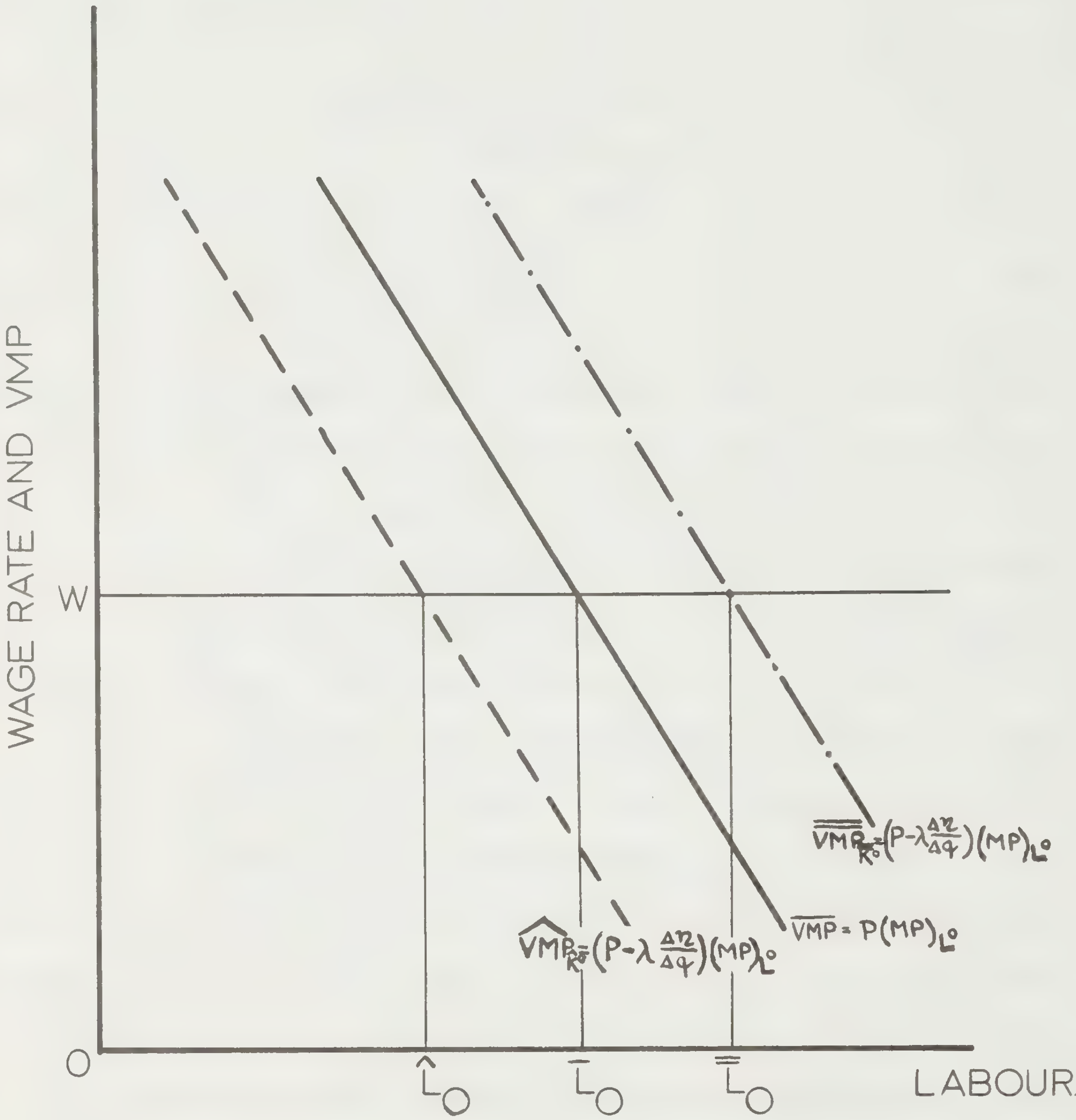
From our model thus far it need not be the case that both labor and capital used to produce output would increase after

a pollution constraint is imposed. Neither must output decrease unambiguously from our model. Let us analyse the situation graphically.

Suppose first that capital is fixed and only labor is free to vary. Let there be no pollution constraint so that the value of the marginal product of labor is price times the marginal product of labor - in our notation $P(MP)_L0$. Thus the value-of-marginal product function is $\overline{VMP} = P(MP)_L0$ in Figure 1. The firm uses labor up to the point that VMP equals the wage rate at $O\bar{L}$ units. After a pollution constraint is imposed with a fixed amount of capital, $\hat{K}^{\circ}$, the value of marginal product curve becomes $\widehat{VMP}_{\hat{K}^{\circ}} = (P-\lambda\frac{\Delta\eta}{\Delta q})(MP)_L0$. The firm now uses $\hat{L}_0$ units of labor, and output also must fall. But if capital is free to vary also, it is possible for the new curve at the new level of capital usage, $\bar{K}^{\circ}$, to shift upward to $\overline{\overline{VMP}}_{\bar{K}^{\circ}} = (P-\lambda\frac{\Delta\eta}{\Delta q})(MP)_L0$. In this case the firm would increase labor usage to OL_0'. One cannot say unambiguously what happens to output.

Or one possible situation could be as depicted in Figure 2. When the firm is free to pollute as much as it wishes, the profit function is given by $\Pi_{\bar{\eta} \to \infty}$. Maximum profit is attained at output $O\bar{q}$. Next let the pollution constraint be imposed at $\bar{\eta}$; the profit function is now shown as $\Pi_{\eta \leq \bar{\eta}}$. Until output Oq' the firm pollutes less than the constraint and profits are the same whether or not the firm is constrained. Since at outputs greater than Oq' the constraint becomes effective, profits are lower at every larger output. That is, at outputs larger than Oq' the firm must use resources to decrease pollution, and these resources are costly.

FIGURE 1 (CHAPTER VII)



But profits may attain a maximum at a larger output than that at which unconstrained profits are maximized. This situation is shown in Figure 2 where the constrained profit maximizing output is $O\acute{q}$, which is greater than the unconstrained $O\bar{q}$. It will be shown below that under rather realistic assumptions about the production function this type of situation cannot occur. It is not, however, apparent from the model set forth in equations (7) - (11).

To get at the problem more rigorously we assumed that a pollution constraint that had been long imposed was parametrically changed. We then (as shown in Appendix D) displaced equations (7) - (11) subject to $\Delta\eta \neq 0$. To obtain the results that we set forth below, we imposed mathematically several rather realistic assumptions.

We assumed first that all inputs are subject to diminishing marginal productivity. Thus,

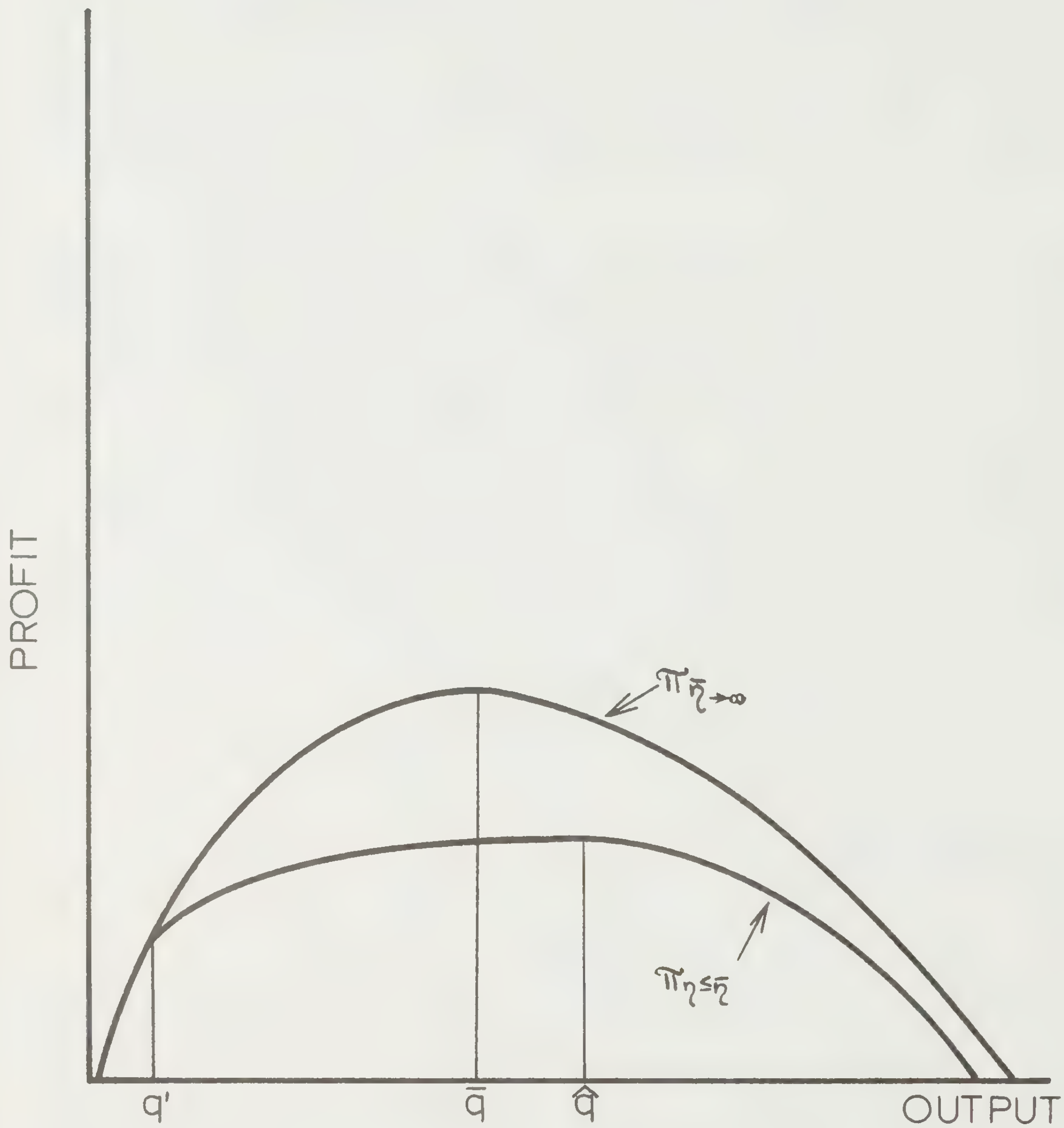
(14) $$\frac{\Delta(MP)_L{}^0}{\Delta L^0} < 0 \text{ and } \frac{\Delta(MP)_K{}^0}{\Delta K^0} < 0,$$

and

(15) $$\frac{\Delta(MP)_L{}^1}{\Delta L^1} > 0 \text{ and } \frac{\Delta(MP)_K{}^1}{\Delta K^1} > 0.$$

Equation (14) is obvious. In (15) recall that the marginal product in pollution reduction is negative. Thus if marginal product decreases, it becomes larger (approaches zero) algebraically. We assume also that an increase in one productive input increases the marginal product of the other productive input and that increases in one

FIGURE 2 (CHAPTER VII)



pollution-reducing input increases (absolutely) the marginal product of the other pollution-reducing input. We assume that the rate of pollution ($\Delta\eta/\Delta q$) can increase , decrease, or remain constant with changes in output.

From the mathematics in Appendix D we deduced unambiguously that

$$(16) \qquad \frac{\Delta L_0}{\Delta\bar{\eta}} > 0 \text{ and } \frac{\Delta K^0}{\Delta\bar{\eta}} > 0.$$

These results indicate that theoretically the labor and capital used to produce output are increased when an increase in the amount of pollution allowed in a period is enacted. Productive labor and capital are reduced when the pollution restriction is tightened. This result is as expected but it could not be proven without the use of mathematics.

Since labor and capital both increase (decrease) from an increase (decrease) in the permissible pollution, output always varies directly with the amount of pollution allowed. Again this result was expected but was certainly not transparent when the model was first set up.

However, while the effect of changes in $\bar{\eta}$ upon output and productive labor and capital can be unambiguously determined, the effects of changes in the pollution restriction upon the resources used in pollution reduction, L_1 and K_1, and therefore upon total resource usage are in some cases not transparent.

Obviously, if one goes from no constraint ($\bar{\eta} \to \infty$) to some finite constraint, $\bar{\bar{\eta}}$, the usage of labor and capital used to

reduce pollution cannot decrease since L^1 and K^1 are both zero when there is no constraint. However, if one goes from a finite constraint to another finite constraint the effects on L^1 and K^1 are ambiguous, and depend upon what is assumed about the way in which changes in output affect the rate of pollution; that is, the effect varies according as

$$(17) \qquad \frac{\Delta(\Delta\eta/\Delta q)}{\Delta q} \lesseqgtr 0.$$

Quite possibly in a large number of cases the most appealing assumption is that equation (17) equals zero: that is, output creates pollution at a constant rate. For example, one ton of minerals extracted produces a certain level of pollution of surface water and of air no matter whether that ton is the first or the last produced. It is shown in Appendix D that with a constant marginal rate of pollution $\Delta L^1/\Delta\bar{\eta}$ and $\Delta K^1/\Delta\bar{\eta}$ are negative. In this case input usage to reduce pollution increases when the restriction is tightened ($\bar{\eta}$ decreases) and decrease when the restriction is relaxed somewhat ($\bar{\eta}$ increases). In this case one cannot derive unambiguously the effect upon total labor and total capital, because from (16) the effects are to some extent offsetting. When $\bar{\eta}$ decreases, less labor and capital are used to produce output and more are used to reduce pollution. The total depends on the relative size of the two effects. Similarly, it is shown that when equation (17) is negative (pollution increases with output but at a decreasing rate), L^1 and K^1 also vary inversely with the amount of allowable pollution, $\bar{\eta}$. *In both the*

above cases the more stringent the restriction upon how much the firm can pollute, the more labor and capital used to reduce pollution.

This deduction seems logical. We have shown above that productive labor and capital, L^0 and K^0, are increased when the allowable pollution is increased. Therefore, output increases also. If the firm is allowed to pollute more, it will reach a new equilibrium at which the returns to labor and to capital are the same in each use. It will do this in two ways; by increasing output, and hence pollution, and by decreasing the amount of labor and capital used to decrease pollution. It would not use the same amounts of anti-pollution inputs while increasing output until the point at which the new restriction is reached. With (17) negative or equal to zero the returns to additional productive inputs fall as their usage increases. Therefore, the firm can increase profits by decreasing the costs involved in pollution prevention, because the returns in this area are now smaller than before. Analysis is similar for a tightening of the restriction. Thus in these cases the change in the usage of an input in pollution reduction to a greater or lesser extent offsets the change in usage in production.

On the other hand we have shown in the Appendix that when equation (17) is positive, that is when increased output leads to an increased rate of pollution, $\Delta L^1/\Delta\bar{\eta}$ and $\Delta K^1/\Delta\bar{\eta}$ <u>may be positive</u>, although not necessarily. This circumstance can only occur under rather stringent mathematical conditions, but theoretically it can occur. If $\Delta L^1/\Delta\bar{\eta}$ and $\Delta K^1/\Delta\bar{\eta}$ are positive it must be because the

marginal pollution cost for increases in output falls so much that the marginal returns to productive labor and capital increase over a range. The firm finds it profitable to increase output beyond the level at which the new constraint is reached and then to reduce pollution to the constraint with more rather than with less anti-pollution labor and capital. In any case $\Delta L^1/\Delta\bar{\eta}$ and $\Delta K^1/\Delta\bar{\eta}$ cannot be positive over the entire range of possibilities. If there is no restriction, that is if $\bar{\eta} \to \infty$, then no L^1 or K^1 is used. When a relevant restriction is imposed marginally, $\bar{\eta}$ is reduced, and some L^1 and K^1 are used. Thus in this instance L^1 and K^1 must vary inversely with $\bar{\eta}$.

In any case an increase in the permitted pollution causes an increase in output, productive labor, and productive capital. ***From the equations set forth one cannot predict what happens to total labour and capital.*** When $\frac{\Delta(\Delta\eta/\Delta q)}{\Delta q} \leqq 0$, anti-pollution labor and capital are decreased, which offsets to a greater or lesser extent the increase in productive labor and capital. When $\frac{\Delta(\Delta\eta/\Delta q)}{\Delta q} > 0$, L^1 and K^1 may increase or decrease. A priori one would suppose that the increase in productive labor and capital would more than offset any reduction in the other type. But further analysis must be empirical in nature. The opposite effects hold for a tightening of pollution standards. This about exhausts the theoretical analysis of a specified constraint on the amount of pollution permitted in each time period.

Now let us turn to the case in which there is no restriction upon the amount of pollution in each period, but at the end of some relevant period of time the environment must be returned to

some specified level. Assume the same production function as in the above model, $q_t = f(L_t, K_t)$, the same return to capital, the same wage rate, and a time horizon of H periods. Total pollution is a function of the rate of output in each period. We call the new total pollution function

$$\eta = h(q_1, q_2, q_3, \ldots, q_H). \tag{18}$$

For simplicity, this time we will assume a constant marginal rate of pollution at all outputs over all periods, i.e., equation (17) equals zero. If we did not make this assumption, the rate of pollution in each period would depend upon the level of output in each preceding period. This complication would make the problem almost unmanageable mathematically. We will make two other simplifying assumptions for mathematical simplicity. First the firm expects a constant input and output price level over the horizon. Secondly, we assume that the firm waits until the period after its production horizon to clean up any pollution and attain the allowed level. In other words we assume the pollution prevention function is

$$\eta = \psi(L_{H+1}, K_{H+1}) \tag{19}$$

and that $\Delta\eta/\Delta L_{H+1}$ and $\Delta\eta/\Delta K_{H+1}$ are negative. All equation (19) says is that the firm will use labor and capital in all periods until H. Then it will use labor and capital in the next period to reduce the total pollution to an acceptable level, that is, to the required level. We make the same assumptions as above about the

marginal products of labor and capital in production and in pollution reduction.

Since the firm expects prices to remain constant it seems logical to assume that it would postpone pollution reduction as long as possible. A unit of input now costs its wage rate; a unit t periods from now costs $[(1/(1+r)^t]$ times its wage rate. The firm increases profit by postponing costs. It also seems consistent with observation to suppose that the firm would wait until the end of a period of production to plant trees, for example, or to reclaim land in some other way.

Under the above assumptions, the present value function to be maximized is

$$PV = \sum_{t=1}^{H} \frac{1}{(1+n)^t} \{Pf(L_t, K_t) - wL_t - (r+d)K_t\} - \ldots$$

(20)
$$- \frac{1}{(1+r)^{H+1}} (wL_{H+1} + (r+d)K_{H+1})$$

subject to

$$[\hat{\eta} - h(q_1, q_2, \ldots, q_H) - \psi(L_{H+1}, K_{H+1})] = 0.$$

where $\hat{\eta}$ is the permitted environmental level after production has ceased.

As would be expected the first order conditions are quite similar to those in the above model in which pollution was constrained in each period. From the mathematics in Appendix D we derived the following five equilibrium conditions:

$$(21 \qquad \hat{\eta} - h(q_1, \ldots, q_H) - \psi(L_{H+1}, K_{H+1}) = 0$$

$$(22) \qquad (P - \lambda\Delta\eta/\Delta q_t)(MP)_{L_t} = w \quad (t=1, \ldots, H)$$

$$(23) \qquad (P - \lambda\Delta\eta/\Delta q_t)(MP)_{L_t} = (r+d) \quad (t=1, \ldots, H)$$

$$(24) \qquad -\lambda\Delta\eta/\Delta L_{H+1} = w$$

$$(25) \qquad -\lambda\Delta\eta/\Delta L_{H+1} = (r+d)$$

Equation (21) shows simply that the constraint must be met. Equations (22) and (23) show that the firm uses labor and capital in each period until the full value of each marginal product equals the respective rate of return. The full value is not simply price times the marginal product. It is price less the shadow price of a reduction in the constraint (λ) times the rate at which output increases pollution, all times the marginal product. A unit of output is worth to the firm the price of that output less the value of the pollution caused by that output. Equation (24) and (25) indicate that the firm will use labor and capital to reduce pollution in period (H+1) until the marginal product of each input in this activity times the value of this activity, λ, equals the rate of return. The right-hand sides of (24) and (25) are positive since the marginal products in pollution reduction are negative and λ is positive.

In Appendix D we let there be some finite constraint $\hat{\eta}$, then we changed the constraint marginally and derived the results under the above assumptions. We found that $\Delta K_t/\Delta\hat{\eta}$ and $\Delta L_t/\Delta\hat{\eta}$ were positive for all $t \leq H$. A relaxation in the constraint increased factor usage. The effect of changes in pollution standards upon output and productive inputs is similar whether the restraint is imposed during production or after production has ceased. *The effect of post-production constraints is less severe because payment to the inputs that reduce pollution are less than payments in the present period.* That is, further payments are discounted into the future. The effect of changes in $\hat{\eta}$ upon labor and capital used to reduce pollution were unambiguous under the present assumptions. An increase (decrease) in the amount of pollution allowed decreases (increases) the amount of labor and capital used to reduce pollution.

To summarize, when the pollution restriction is postponed, productive labor and capital and hence output vary directly with the amount of pollution permitted. The restriction is not so severe when the reduction can be postponed because factor payments are discounted. The amounts of labor and capital used to reduce pollution vary inversely with the amount of pollution permitted. One cannot say a priori what happens to the total labor and capital used, although quite probably the productive effect dominates.

The effects of pollution standards on capital equipment are easily dealt with. A pollution standard on something like exhaust fumes is the same as an increase in the price of capital, because

the standard simply raises the operating cost. Therefore, this case can be treated exactly as economists treat the theory of factor demand. From this theory it has been shown that an increase in the price of an input unambiguously decreases the usage of that input both by the firm and the industry. As long as the input is a normal input (normal in the sense that an increase in output induces an increase in the input at constant input prices) an increase in its price reduces output. The effect of a change in an input's price on the usage of another input cannot be deduced a priori without further restricting assumptions. In the case discussed here, an increase in the price of capital would no doubt decrease the usage of labor, since these are the only two inputs.

To summarize, for the firm, in all cases an increase in the severity of environmental controls will decrease output. In all cases this will decrease the usage of productive capital and labor -i.e., decrease investment and employment. In all probability since productive labor and capital outweigh the labor and capital used to reduce pollution, both labor and capital usage will decrease.

VII-B. THE INDUSTRY

The static effects of the imposition of environmental controls upon mining industries is two-fold. The primary effect is through the impact upon the individual firms making up the industry. This impact has been thoroughly described in the preceding section. The industry will be affected by a multiple of the number of firms surviving times the effect upon the average surviving firms.

In addition, there is the effect of the reduced profits upon marginal firms and upon long-term investment in the industry. *A tightening of environment standards must decrease profits, just as an increase in the rate of taxation decreases them.* The marginal firms - just how many firms are marginal depends upon the original profit situation and upon the severity of the constraints - will find that they cannot cover opportunity costs and in the long run they will leave the industry. Marginal deposits that were previously profitable to exploit will become unprofitable at the going prices. The situation will be similar to that described in the case of taxation. Similarly, the exit of firms will be greater, because the industries are price takers on the world market. As discussed in Chapter VI, when an industry has an effect on commodity price, the increase in price caused by the decreased supply of the exiting firms would cause the impact of the constraint to be less severe. If price does not rise as firms exit, exit will continue longer, because firms or deposits that would be profitable at higher prices cannot cover opportunity costs. Thus as with taxation the impact of constraints is most strongly felt when the industry as a whole has little influence upon the world price. There is little point in repeating the analysis of the dynamic effects of constraints. Anything that distorts the long-run profit situation will dampen investment somewhat. In the case of environmental constraints the dynamic analysis is substantially the same as that discussed in Chapter VI for taxation.

This completes the theoretical analysis of the impact of

taxation and environmental controls upon mining industries. *We do not mean to argue that taxes should not be levied or controls should never be enacted.* We have ignored any benefits of the taxes or of the environmental controls. Certainly there are benefits to both. *Our purpose has been simply to analyse the impact upon the industries, not to analyse the total effect upon society as a whole. We have tried to show that there are costs involved in these regulations and that these costs can be substantial.* Certainly one must weigh these costs against the benefits of the controls before making a decision. The existence of these costs has theoretical implications as we have shown; the magnitude of the costs is an empirical question, to which we now turn.

VIII DATA PROBLEMS AND SOME EMPIRICAL RESULTS

The policy analyst is interested in both qualitative and quantitative impacts of various policy decisions. He wishes to know not only that reducing profit taxes will affect employment but by how much. By developing a formal model and specifying it empirically we can make estimates of the quantitative impact of various policy decisions. Such an empirical specification provides a sound basis for decision making. Unfortunately the data base required to produce an empirical specification of even a simple model, such as developed in Chapters V through VII, is difficult to obtain. Data have historically been collected to yield a chronology of events. As additional data became available series have been redefined so that time trends are often not comparable for any significant length of time.

III-A. DATA REQUIREMENTS

In order to make any empirical estimates, there must exist historical data that yield a record of the impact of past policy changes. The purpose of a formal model is to identify all the relevant parameters which affect the target variables. If we wish to determine the impact of profit taxes on employment, for example we must know the variables other than taxes which affect the firm's and industry's demand for labor. Given the variables which affect employment we may use multiple regression analysis to determine the effect taxes have on employment independent of other parameter changes such as

wage changes, price changes, etc.

No data are totally accurate. What is required for the specification of the employment, investment, and output functions is reasonably accurate data (10% error) so long as the data are systematically biased. Such a systematical bias is more or less assured if the data are collected in the same manner over a prolonged period of time. Changes in the method of data gathering can greatly distort a time series even if the new method is more accurate than the old method. To generate consistent and comparable time series we must attempt to correct the raw data for the changes in the method of collection over time. For example, in 1958 tax data for the mineral industry were collected and presented as a sum of taxes paid by five important divisions of the mineral industry. By 1970, data were collected and presented for six important divisions, by important divisions. Such data can be used in time series analysis only if the various series are developed in overlapping periods and spliced together to generate a single consistent series. Such splicing may be done simply as follows:

Series 1	Series 2	Series 3	Spliced Series (Union)
a_1			$x_1 = a_1$
a_2			$x_2 = a_2$
a_3			$x_3 = a_3$
a_4	b_1		$x_4 = a_4$
	b_2		$x_5 = b_2 \cdot \frac{a_4}{b_1}$
	b_3	c_1	$x_6 = b_3 \cdot \frac{a_4}{b_1}$
		c_2	$x_7 = c_2 \cdot \frac{b_3}{c_1} \cdot \frac{a_4}{b_1}$
		c_3	$x_8 = c_3 \cdot \frac{b_3}{c_1} \cdot \frac{a_4}{b_1}$

If overlappings such as a_4, b_1 and b_3, c_1 are available the splicing procedure is simple but if overlappings do not exist they must be generated from the raw data collected by the data source.

Another problem results from the fact that recorded data are often partly endogenous. For example, let us look at mining taxes. If one takes mining taxes paid divided by total taxable profits to be the definition of the mining tax rate (as is done in the study), several problems are encountered. (1) Output, employment and investment are dependent on the tax rate so that the profit generated and the tax acturally paid show not only the effect of the

rate charged but it shows also the impact of the rate on the firm's behavior. (2) The problem is further complicated by write-off options and tax credits on new investment. Yet the actual tax rate for the industry does not exist since the firms operating in the industry face a tax rate which is dependent on their profit level. For each firm there is a relevant exogenous tax rate but for the industry we must seek some weighted average. One such average might be

$$1) \qquad T_{RI} = \frac{T_{R1} \cdot \Pi_1 + T_{R2} \cdot \Pi_2 + \ldots + T_{Rn} \cdot \Pi_n}{\Pi}$$

where T_{R1} is the mean industry tax rate, T_{R1} is the tax rate on firms in tax classification 1 and Π_1 is the total profits of firms in classification one, and so forth.

Another problem arises from the absence of information. If we know employment and the total wage bill we can gauge average yearly wage per employee, but we do not know if the variance in this figure is due to variations in the wage rate paid or the hours worked.

We then have three major types of data problems: (1) inconsistent methods of collection and inconsistent base units, (2) index number problems in gauging mean values from market data, (3) absence of essential data inputs.

III-B. EMPIRICAL ANALYSIS

The purpose of the empirical analysis below is simply to demonstrate the feasibility of empirical analysis employing the model developed. For demonstration purposes the investment function is estimated for the mineral industry. The investment function is assumed to be linear in the logs of its arguments so that the equation to be estimated is

$$2)\quad \log I = \log \beta_0 + \log \beta_1 w + \log \beta_2 p + \log \beta_3 R + \log \beta_4 T_p + \log \beta_5 \rho T_m$$

Equation (2) is assumed to be linear in the logs of its arguments so that estimated coefficients will be equals to elasticities (i.e., β_1 = % change in I:% change in w). There are no good data on the mean depreciation rate of the industry so that (d) is dropped as an explanatory variable. Such an assumption is equivalent to assuming that the depreciation rate was invariant over the period of analysis. Further, adequate data are presently not available to allow specification of the impact of environmental standards so that the pollution constraint is dropped as a variable.

Since the model of Chapter V is stated in real terms we must deflate the nominal units of price and value data by a price index to convert to real values and eliminate the impact of price inflation:

P_w = A price deflator for Ontario = the wholesale price index for Canada. (The validity of such a proxy depends on the degree to which wholesale price changes in Canada parallel wholesale price changes in Ontario).

For the purpose of the empirical specification of equation (2) the dependent and independent variables are now defined as follows:

$I = C/P_w$, where C = Capital and repair expenditures in the mineral industry of the Province of Ontario = capital and repair expenditures in the mineral industry of Canada.

(The use of Canadian data as a proxy for Ontario data assumes that the proportion of total Canadian mineral investment which has occurred in the Province of Ontario is a constant.)

$w = W/P_w$, where W = mean wage rate in mining in the Province of Ontario = Total wages & salaries bill of the Mining Industry in the Province of Ontario divided by Total Number of Employees. (Such a definition yields a yearly wage but since no information was available on hours worked in mining we cannot determine how much of the variance in W is due to changes in the mean wage rate and how much is due to variance in mean hours worked per year. However, available data on average weekly hours worked in manufacturing show little variance over the 1961 - 1972 period for which data is available. If mining has followed a similar pattern the wage data available may largely reflect changes in the wage rate and not changes in hours worked.)

$p = P/P_w$, where P = a weighted price index of mineral resources produced in the Province of Ontario = wholesale price index of the mining industry (non-ferrous metal). The wholesale price index of the mining industry (non-ferrous metal) is a national price index the weighting of which may differ substantially from the correct weightings for Ontario. The raw prices themselves are probably

acceptable since mineral resources sell on a national and international market.)

R = mean interest rate at which funds are borrowed to invest in capital in the mineral industry in the Province of Ontario = industrial bond yield average (June of each calendar year).

T_p = Provincial corporate income tax rate = estimates supplied by the Ministry of Natural Resources, Province of Ontario.

ρ = The percentage of profit derived from mineral extraction.

T_m = Provincial mining tax rate for Ontario Mining Industry = mining taxes paid in Ontario divided by total Ontario Mining Industry Taxable Profits. (Both taxes paid and taxable profits are dependent on firms' production decisions. Further, the existence of write-offs and other optional decisions makes the series highly variable from year to year.)

Employing multiple regression analysis to estimate the investment function (equation 2) yields

$$\log I = 2.83 + \underset{(1.30)}{1.21 \log w} + \underset{(2.41)^*}{2.64 \log p} - \underset{(-0.03)}{0.03 \log R} \tag{3}$$

$$+ \underset{(0.25)}{0.18 \log T_p} + \underset{(0.26)}{0.77 \log (\rho T_m)} \quad (R^2 = .88)$$

where t values are in parentheses below the estimated coefficients and (*) indicates statistical significance at the 5% level. From equation (3) it is evident that variances in w, p, R, Tp, and ρT_m explain most of the variance in investment (88%). Only one variable can be said to significantly affect investment, when significance

is measured as a 95% confidence interval, the price of mineral resources.

When we institute a step-down procedure to eliminate variables which are least significant until the remaining variables are statistically significant at the 5% level, we generate

$$\log I = 3.11 + \underset{(4.42)^*}{1.42 \log w} + \underset{(3.60)^*}{2.46 \log p} \tag{4}$$

$$(R^2 = .88) \text{ and } (D.\ W. = 1.59)$$

Equation (3) indicates that 88% of the variance in the total investment expenditure of mining firms in the Province of Ontario is explained by variances in the wage rate and the price of mineral resources. The coefficient for the price of mineral resources suggests that a 1% rise in the price index for mineral resources produces a 2.46% increase in real investment in the mining industry of Ontario. The coefficient of the wage rate suggests that a 1% increase in the wage rate faced by the mining industry produces a 1.42% increase in investment in the mining industry of Ontario. The existence of a positive and statistically significant coefficient for the wage rate suggests that labor and capital are substitutes in mining and that as the wage rate rises, other things remaining fixed, the quantity of capital purchased rises to substitute for the more expensive labor.

The coefficient of the interest rate was not statistically significant. This suggests that during the 1956 - 1972 period the effect of prices and wages so dominated investment decisions that the interest rate which varied from 4.44% to 8.34% did not

significantly affect investment decisions.

Likewise, the coefficients for income taxes and mining taxes were not statistically significant. There are, of course, numerous possible explanations for this finding. As far as Provincial corporate income taxes are concerned they did not change very much over the period. They were 7% in 1950, 11% from 1957 - 1966 and 12% from 1967 - 1972. The fact that investment expenditures were not significantly related to profit taxes may therefore simply indicate that in the range of taxes charged the effect taxes had were swamped by price and wage changes. Secondly the fact that profit taxes and mining taxes are not significantly related to investment spending in the mining industry may simply reflect the fact that we have a poor measure of the effective tax rate on profits mining firms face.

FOOTNOTES TO CHAPTER VIII

1) Federal corporate taxes were not included in the study because of the impossibility to obtain, within the time available, the necessary data over a sufficient time period and reduced to a base compatible with available Provincial date. However, Federal corporate taxes, though considerable (50% of profits calculated on a different base) did not change significantly during the 1956 - 1972 period, and were assumed a constant. Their relative magnitude may be gauged from Figures 5 and 6, Chapter II.

2) See Appendix E - 14 for a representative breakdown. Note that from metal mining on the whole Federal corporate income tax revenue is between 3.5 and 4.0 times Provincial corporate income tax revenue.

IX CONCLUSIONS AND DIRECTIONS FOR THE FUTURE

The purpose of the study upon which this paper was based was to develop a preliminary economic model for the Ontario mining industry in order to enable the assessment of the impact of taxation and of environmental legislation upon investment, employment and output, as well as upon entry and exit of firms, and to attempt to verify empirically within the given time and data limitations the impact of some key variables.

We have used a rather general and also rather simple theory to analyze the possible effects of taxation and environmental controls upon the mineral extracting firms and industries. *We have deduced from the model under the general assumptions certain a priori effects upon output, investment, and employment - all of which were found to vary inversely with taxation and the severity of controls to a greater or lesser extent.* We have also attempted to isolate those variables that affect the decisions of the firms.

The report developed step by step suitable firm and industry models. The effect of profit taxation upon the profit maximizing firm within the industry is not fatal as long as the effective tax rate is less than (100% of profits minus opportunity cost). A greater rate leads to exit.

Even an increase to a level lower than 100% reduces entry (which here includes much of what is conventionally referred to as expansion) and thus future output and employment as changes in rates of taxation do not affect risk and uncertainty levels. As some firms in any industry are generally marginal, significant increases

in relative taxation levels lead to exits, a reduction in the number of firms, reduction in production levels and reduction of ore reserves. *If it is a policy goal to reduce output and employment as little as possible, the worst type of industry to tax heavily is one that sells on world markets.* Changes in taxation levels have three effects upon tax revenues, only the first of which is generally considered: The direct effect, if aggregate profit levels remain the same, and the effects due to a fall in the number of firms and due to a fall in the profit level of the average firm. The latter effects can overwhelm the former.

Types of environmental controls were classified and the effects of changes in emission controls traced through the model paralleling the preceding analysis of taxation changes. Within the limits of this project a detailed analysis of ambient controls which raises a host of additional problems was not incorporated. *On the firm level a tightening of restrictions leads to a reduction in output but effect on input usage is generally ambiguous.* Analysis is then extended to the industry and this difference between the effects of taxation and of environmental legislation changes is multiplied. While the effects of both are thus in the same direction as regards exit and entry, changes in environmental constraints affect surviving firms in ways that changes in profits taxation do not.

Chapter VIII first focused on the weaknesses in the existing data base - much Statistics Canada material is virtually useless for serious analysis - and pointed to future data requirements. Although empirical analysis was constrained by data limitations,

stepdown multiple regression yielded some interesting results. Over the past two decades, effects of taxation changes, if any, were swamped by changes in metal prices and labour costs. 88% of variance in total investments is explained by changes in these two variables. A one percent increase in the price index for minerals results in a 2.46% increase in investment (expansion) and a one percent increase in the wage rate leads to a 1.42% increase in capital investment (substitution).

The first requirement for further empirical analysis is the development of an adequate data base.

The pilot study confined itself to the impact of the two major types of taxation imposed by the Province: the Provincial corporate income tax and the Provincial mining tax.[1] But government extracts revenues from the mineral industry also by other means, such as acreage taxes, royalties, licences and mining leases.[2] It is conceivable that, for instance during extended periods of very low metal prices, these forms of "taxation" may assume greater importance than at present. Also, their rates may be changed. Other jurisdictions impose taxes upon gross revenue, upon reserves and upon capital assets. Anticipating discussion of such "other" forms of taxation, incorporation of the analysis of their effects is required for the development of a truly comprehensive model. The same is true for the economic analysis of such instruments as processing allowances for tax calculations.

The analysis of environmental controls confined itself to the effects of simpler types of constraints. Expansion is

required with respect to ambient controls, constraints not upon the individual firm but upon the total amount of pollution in a given environment. This type of situation leads to externalities in that any one firm acting alone imposes pollution costs on all firms in the area inasmuch as its pollution adds to the total.

Another important facet to be developed will be the analysis of environmental controls on the firm's investment in capital. Whereas the firm hires labor and many other inputs by the hour, the day, the week, etc., it generally owns its capital. In this case capital is a stock rather than simply a flow. But under the assumption of capital ownership we can deduce the effect of controls upon the age of the capital owned and upon the rate of depreciation. This will involve a model that is rather complex. Also considered must be the way in which the rate of pollution in one period affects the rate in other periods. This change also complicates the model a great deal. As work proceeds it is quite probable that further theoretical modifications will arise.

Possibly another direction in further theoretical analysis would be to adapt the models to specific mineral industries. Each industry has its own peculiar characteristics. The models set forth above have been general models, in which a broad general approach is taken. If one wished to learn the specific effects one must use more specifically oriented theories that incorporate the specific characteristics of the firms and industry. This approach, combined with rigorous empirical analysis would give a much better insight into the individual cases a policy maker

wished to analyze. Of course, the generality of the theory set forth above would be lost. Yet another possible extension would be to complicate the general analysis by assuming, for example, interdependence among the different periods - that is, by using a more dynamic approach. That approach would be useful only to the extent that it gives a better general insight. Complication for the sake of complication certainly has no place in any economic theory. Probably the most useful approach would be to make the general theory more specific in order to analyze industries or groups of industries. We have as noted ignored these peculiar institutional characteristics for the sake of generality.

Lastly another phase of possible development would be to integrate the model of the mining industry into a general macro model of the Ontario economy. Such a model would give the policy analyst an index of the impact the mining industry's employment, output and investment expenditures have on the Province as a whole. The macroeconomic model would yield the full ramifications on the Ontario economy of changes which occur in the mining industry and could be used in conjunction with national models such as the Candide model to gauge the national impact of changes which occur in the Ontario mining industry.

Appendix A: Sections 91, 92 and 109 of The British North America Act

From:

A Consolidation of

THE BRITISH NORTH AMERICA ACTS

1867 to 1965

Prepared by

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Powers of the Parliament.

91. It shall be lawful for the Queen, by and with the Advice and Consent of the Senate and House of Commons, to make Laws for the Peace, Order, and good Government of Canada, in relation to all Matters not coming within the Classes of Subjects by this Act assigned exclusively to the Legislatures of the Provinces; and for greater Certainty, but not so as to restrict the Generality of the foregoing Terms of this Section, it is hereby declared that (notwithstanding anything in this Act) the exclusive Legislative Authority of the Parliament of Canada extends to all Matters coming within the Classes of Subjects next herein-after enumerated; that is to say, -

1. The amendment from time to time of the Constitution of Canada, except as regards matters coming within the classes of subjects by this Act assigned exclusively to the Legislatures of the Provinces, or as regards rights or privileges by this or any other Constitutional Act granted or secured to the Legislature or the Government of a Province, or to any class of persons with respect to schools or as regards the use of the English or the French language or as regards the requirements that there shall be a session of the Parliament of Canada at least once each year, and that no House of Commons shall continue for more than five years from the day of the return of the Writs for choosing the House: provided, however, that a House of Commons may in time of real or apprehended war, invasion or insurrection be continued by the Parliament of Canada if such continuation is not opposed by the votes of more than one-third of the members of such House.

1A. The Public Debt and Property.

2. The Regulation of Trade and Commerce.

2A. Unemployment insurance.

3. The raising of Money by any Mode or System of Taxation.

4. The borrowing of Money on the Public Credit.

5. Postal Service.

6. The Census and Statistics.

7. Militia, Military and Naval Service, and Defence.

8. The fixing of and providing for the Salaries and Allowances of Civil and other Officers of the Government of Canada.

9. Beacons, Buoys, Lighthouses, and Sable Island.

10. Navigation and Shipping.

11. Quarantine and the Establishment and Maintenance of Marine Hospitals.

12. Sea Coast and Inland Fisheries.

13. Ferries between a Province and any British or Foreign Country or between Two Provinces.

14. Currency and Coinage.

15. Banking, Incorporation of Banks, and the Issue of Paper Money.

16. Savings Banks.

17. Weights and Measures.

18. Bills of Exchange and Promissory Notes.

19. Interest

20. Legal Tender.

21. Bankruptcy and Insolvency.

22. Patents of Invention and Discovery.

23. Copyrights.

24. Indians, and Lands reserved for the Indians.

25. Naturalization and Aliens.

26. Marriage and Divorce.

27. The Criminal Law, except the Constitution of Courts of Criminal Jurisdiction, but including the Procedure in Criminal Matters.

28. The Establishment, Maintenance, and Management of Penitentiaries.

29. Such Classes of Subjects as are expressly excepted in the Enumeration of the Classes of Subjects by this Act assigned exclusively to the Legislatures of the Provinces.

And any Matter coming within any of the Classes of Subjects enumerated in this Section shall not be deemed to come within the Class of Matters of a local or private Nature comprised in the Enumeration of the Classes of Subjects by this Act assigned exclusively to the Legislatures of the Provinces.

Exclusive Powers of Provincial Legislatures.

92. In each Province the Legislature may exclusively make Laws in relation to Matters coming within the Classes of Subject next herein-after enumerated; that is to say, -

1. The Amendment from Time to Time, notwithstanding anything in this Act, of the Constitution of the Province, except as regards the Office of Lietenant Governor.

2. Direct Taxation within the Province in order to the raising of a Revenue for Provincial Purposes.

3. The borrowing of Money on the sole Credit of the Province.

4. The Establishment and Tenure of Provincial Offices and the Appointment and Payment of Provincial Officers.

5. The Management and Sale of the Public Lands belonging to the Province and of the Timber and Wood thereon.

6. The Establishment, Maintenance, and Management of Public and Reformatory Prisons in and for the Province.

7. The Establishment, Maintenance, and Management of Hospitals, Asylums, Charities, and Eleemosynary Institutions in and for the Province, other than Marine Hospitals.

8. Municipal Institutions in the Province.

9. Shop, Saloon, Tavern, Auctioneer, and other Licences in order to the raising of a Revenue for Provincial, Local, or Municipal Purposes.

10. Local Works and Undertakings other than such as are of the following Classes:-

(a) Lines of Steam or other Ships, Railways, Canals, Telegraphs, and other Works and Undertakings connecting the Province with any other or others of the Provinces, or extending beyond the limits of the Provinces;

(b) Lines of Steam Ships between the Province and any British or Foreign Country;

(c) Such Works as, although wholly situate within the Provinces, are before or after their Execution declared by the Parliament of Canada to be for the general Advantage of Canada or for the Advantage of Two or more of the Provinces.

11. The Incorporation of Companies with Provincial Objects.

12. The Solemnization of Marriage in the Province.

13. Property and Civil Rights in the Province.

14. The Administration of Justice in the Province, including the Constitution, Maintenance, and Organization of Provincial Courts, both of Civil and of Criminal Jurisdiction, and including Procedure in Civil Matters in those Courts.

15. The Imposition of Punishment by Fine, Penalty, or Imprisonment for enforcing any Law of the Province made in relation to any Matter coming within any of the Classes of Subjects enumerated in this Section.

16. Generally all Matters of a merely local or private Nature in the Province.

109. All Lands, Mines, Minerals, and Royalties belonging to the several Provinces of Canada, Nova Scotia, and New Brunswick at the Union, and all Sums then due or payable for such Lands, Mines, Minerals, or Royalties, shall belong to the several Provinces of Ontario, Quebec, Nova Scotia, and New Brunswick in which the same are situate or arise, subject to any Trusts existing in respect thereof, and to any Interest other than that of the Province in the same.

APPENDIX B: MATHEMATICAL APPENDIX TO CHAPTER V

As noted in the introduction to Chapter V, many of the theoretical implications of taxation and environmental controls can, because of the complexity of the problems involved, only be derived with the use of mathematics. All of these mathematical derivations are set forth below in this and the following two appendices. Here we make no attempt at economic analysis, leaving all interpretation for the major body of the text.

Section 1 sets forth the basic principles of comparative statics and section 2 concerns the formal model of the firm. Appendices C and D derive the implications of changing the rates of taxation and environmental controls respectively.

B.1. - COMPARATIVE STATICS

In doing comparative statics the theorist generally sets up a system of equations that specifies an equilibrium.[1] For example, the system might be

$$
(1)\qquad
\begin{array}{l}
f^1 (x_1, x_2, x_3, \ldots, x_n; \alpha_1, \alpha_2, \ldots, \alpha_m) = 0 \\
f^2 (x_1, x_2, x_3, \ldots, x_n; \alpha_1, \alpha_2, \ldots, \alpha_m) = 0 \\
f^3 (x_1, x_2, x_3, \ldots, x_n; \alpha_1, \alpha_2, \ldots, \alpha_m) = 0 \\
\vdots \\
f^n (x_1, x_2, x_3, \ldots, x_n; \alpha_1, \alpha_2, \ldots, \alpha_m) = 0
\end{array}
$$

where the x_i's are the variables endogenously determined by the system of equations and the α_j's are parametrically determined outside of the system. Theoretically, since the number of equations equals the number of unknowns, we can solve (1) for each x_i in terms of the α_j's to get the unique solutions

$$(2) \qquad x_k = \phi^k(\alpha_1, \alpha_2, \alpha_3, \ldots, \alpha_m). \quad (k = 1, 2, \ldots, n)$$

Equations (2) simply specify the values taken by each x_i for specific values of the parameters, $(\alpha_1, \ldots, \alpha_m)$.

The objective of comparative statics is to obtain $dx_k/d\alpha_j$; that is, the rate at which a change in the j-th parameter changes the k-th variable when all or some specified subset of the x's are allowed to vary optimally. Optimal variation means that equations (1) are satisfied both before and after the parametric change in α_j. Normally, in fact almost always, one would allow only one of the parameters to change at a time. If two or more parameters changed at the same time, one could generally not isolate the effect of either parameter from the effect of the other.

Economists usually assume (as is done in Chapters V-VII) that the system of equations, such as (1), specifies the equilibrium condition for either a maximization or minimization problem. In addition, economists often assume simply that the systems of equations are dynamically stable. That is, if the system is disturbed the variables return to these equilibrium values. This assumption places restrictions upon the system that aid in determining the sign of the derivatives after a parametric change.

Since maximization is assumed here, that aspect will be stressed.

If equations (1) result from maximization, then the n x m matrix

$$[f_i^j\ (x_1, x_2, \ldots, x_n; \alpha_1, \alpha_2, \ldots, \alpha_m)] \quad (i, j = 1, 2, 3, \ldots, n)$$

is associated with a negative definite quadratic form, where $f_i^j(x_k, \alpha_r)$ is $\partial f^j/\partial x_i$. That is, the principal minors of the determinant associated with $[f_i^j]$ alternate in sign beginning with

$$(3) \qquad (-1)^n \begin{vmatrix} f_1^1 & f_2^1 & f_3^1 & \cdots & f_n^1 \\ f_1^2 & f_2^2 & f_3^2 & \cdots & f_n^2 \\ f_1^3 & f_2^3 & f_3^3 & \cdots & f_n^3 \\ \vdots & \vdots & \vdots & & \vdots \\ f_1^n & f_2^n & f_3^n & \cdots & f_n^n \end{vmatrix} > 0$$

Thus if n is even, the determinant if positive; if odd, negative. All (n-1) x (n-1) principal minors are of opposite sign. For example if n is even, the determinant obtained by eliminating the j-th row and i-th column is negative. All (n-2)x(n-2) principal minors revert to the sign of the determinant in (3) and so forth, down to $f_i^i < 0$ for all i's. The assumption of maximization,

and thus the negative definiteness of the matrix of derivatives (or minimization and the assumption of positive definiteness) enables one to sign many of the derivatives obtained with comparative statics. This result holds precisely only for unconstrained maximization. The rules concerning constrained maximization will be reviewed later.

After setting up the equilibrium system the next step is to allow one of the parameters to change and force equilibrium both before and after the change, while permitting variation in all of the endogenous variables. To this end assume that α_k changes parametrically. Take the total differential of system (1) to obtain

$$\sum_{j=1}^{n} f_j^1 \, dx_j = - f_{\alpha_k}^1 \, d\alpha_k$$

$$\sum_{j=1}^{n} f_j^2 \, dx_j = - f_{\alpha_k}^2 \, d\alpha_k$$

$$\vdots$$

(4)

$$\sum_{j=1}^{n} f_j^k \, dx_j = - f_{\alpha_k}^k \, d\alpha_k$$

$$\vdots$$

$$\sum_{j=1}^{n} f_j^n \, dx_j = - f_{\alpha_k}^n \, d\alpha_k$$

The solution to system (4) is given by

(5) $$\frac{dx_j}{d\alpha_k} = \frac{-\sum_{i=1}^{n} f^i_{\alpha_k} F_{ij}}{F}, \quad (j = 1, 2, \ldots, n)$$

where F is the determinant in (3) associated with the negative definite quadratic form and F_{ij} is the cofactor of the i-th row and j-th column of F. Obviously nothing can be said a priori about the sign of (5). Assume however that α_k enters only into the k-th equation and that we are interested in the sign of $dx_k/d\alpha_k$. The solution is

$$\frac{dx_k}{d\alpha_k} = \frac{-f^k_{\alpha_k} F_{kk}}{F}.$$

Since F_{kk} is an (n-1) x (n-1) principal minor of F and we assume maximization, F_{kk} is of opposite sign from F. Since F_{kk}/F must be negative the sign of $dx_k/d\alpha_k$ depends upon what we assume or know about the sign of $f^k_{\alpha_k}$. Other types of equations and systems of equations will be used in this appendix, but the methodology will always be similar to that described here.

B.2. - MATHEMATICAL MODEL OF THE FIRM

Each mineral extracting firm attempts to maximize the present value of its stream of profits, written as

(6) $$PV\,\pi = \pi_0 + (\frac{1}{1+r})\pi_1 + (\frac{1}{1+r})^2\pi_2 + \ldots + (\frac{1}{1+r})^H\pi_H =$$

$$\sum_{t=0}^{H} (\frac{1}{1+r})^t \pi_t,$$

where π_i is the expected profit in the i-th period, r is the rate of interest, and period H is the last period in the firm's time horizon. The interest rate is assumed to remain constant and the rate of profit in one period is independent of the rate in any other period. The firm's production function in its most general form is stated as

$$(7) \qquad q = f(x_1, x_2, \ldots, x_n)$$

where q is the quantity of physical output and the x_i's are the quantities of physical inputs per unit of time. The $\partial q/\partial x_i = f_i$ are all positve and diminish in all directions over the relevant range.

Under these assumptions the present value of the firm can be written as

$$(8) \qquad PV = \sum_{t=0}^{H} \left(\frac{1}{1+r}\right)^t \{P_t f(x_{1t}, x_{2t}, \ldots, x_{Ht}) - \sum_{i=1}^{n} P_{it} x_{it}\},$$

where P_t is commodity price in the t-th period, P_{it} and x_{it} are the usage price and the quantity used of the i-th input during the t-th period. Maximization requires that for every period

$$(9) \qquad \left(\frac{1}{1+r}\right)^t (P_t f_i - P_{it}) = 0, \ (i = 1, 2, \ldots, n)$$

which implies that $P_t f_i = P_{it}$, i.e., the value of each factors' marginal product equals its price in every period.

For simplicity and analytical convenience let us take land, management, and ingredient inputs as given and assume that there

are only two factors of production necessary to produce output; call these labor (L) and capital (K). In this case, equation (9), the equilibrium conditions are

$$\text{(10)} \qquad \begin{aligned} &\text{a)} \quad P_t f_{L_t} - W_t = 0 \\ &\text{b)} \quad P_t f_{K_t} - (r+d) = 0 \end{aligned}$$

for every t, where $f_{L_t} = \partial q/\partial L_t$ and $f_{K_t} = \partial q/\partial K_t$. W_t is the wage rate, and d is the rate of capital depreciation. Second order conditions require that the matrix [F] , where $[F] = [f_{ij}]$, is associated with a negative definite quadratic form for each time period.

From equation (10) the firm's demand for labor and capital can be expressed as functions of the parameters of the system.

$$\text{(11)} \qquad \begin{aligned} L_t &= L_t(W_t, P_t, r, d) \\ K_t &= K_t(W_t, P_t, r, d). \end{aligned}$$

Furthermore,

$$\text{(12)} \qquad q_t = q_t(W_t, P_t, r, d).$$

One can displace equations (10) and show that the rates of change of labor and capital with respect to their own prices, W, and (r+d) are negative. The signs of the other derivatives are indeterminate without additional assumptions.

FOOTNOTE TO APPENDIX B

1. For a more thorough exposition of the methodology of comparative statics see P.A. Samuelson, *Foundations of Economic Analysis*, Atheneum, New York, 1965, especially Chapters II and III.

APPENDIX C: MATHEMATICAL APPENDIX TO CHAPTER VI

A profits and a mining tax of T_p and PT_n repectively, would leave the firm a net profit in any time period of

(13) $$\pi_n = (1-T_p)(1 - \rho T_n)\pi$$

where π is total profit, ρ is the percentage of profit derived from mineral extraction, and T_n is the mining tax rate. Profit maximization requires

(14)
$$\frac{\partial\pi}{\partial L} = (1 - T_p)(1 - \rho T_n)\frac{\partial\pi}{\partial L} = 0$$
$$\frac{\partial\pi}{\partial K} = (1 - T_p)(1 - \rho T_n)\frac{\partial\pi}{\partial K} = 0$$

Since T_n and T_p are between zero and one, the solution requires $\partial\pi/\partial L = 0$ and $\partial\pi/\partial K = 0$, the same solution as the conditions when the tax rates are zero. Therefore, at any level of taxation, L,K, and q are unchanged under the tax so long as the firm remains in business.

If the mining or the corporate income tax rate is increased, the effect upon tax revenues of the government is three-fold. If $\bar{T}$ is the average rate of taxation $(0 < \bar{T} < 1)$, π is the average rate of profit in the industry, and N the number of firms in the industry, the total revenue from a tax is

$$R = \bar{T}N\pi$$

A change in the rate of taxation changes revenue in the following

way

$$\frac{dR}{dT} = N\pi \frac{d\bar{T}}{dT} + \bar{T}\pi \frac{dN}{dT} + \bar{T}N \frac{d\pi}{dT} \tag{15}$$

The first term of (15) is the additional amount of taxes if the total level of industry profits remained the same after the average tax rate rises. If taxes go up 10%, for example, $(\frac{d\bar{T}}{dT} = .1)$ and initial industry profits are \$100 million, $N\pi \frac{d\bar{T}}{dT}$ = \$100 million x .1 = \$10 million. The second term of (15) $\bar{T}N \frac{dN}{dT}$ is the effect the fall in the number of firms caused by the tax increase has on tax collection. Clearly if the tax rate rises, and if some alternative costs are taxed, marginal firms will leave the industry and $(\frac{dN}{dT}) < 0$. The third term of (18), $\bar{T}N (\frac{d\pi}{dT})$ is the effect that the tax rate increase has on the profit rate of the average firm. $(\frac{d\pi}{dT})$ will be negative and its absolute value will be larger the smaller the control the firm and industry exercise over price. For an industry engaged in international sales such as the Ontario mining industry we would expect the absolute value of $\frac{dN}{dT}$ and $\frac{d\pi}{dT}$ to be large relative to an industry that sells its product on the domestic market. Therefore the effect of taxes on the employment, investment and output decisions of the mining industry would be expected to be larger than for industries that largely sell in the domestic market.

Needless to say, it is certainly conceivable that the second two terms, both of which are negative, could overwhelm the first term, which of course is positive. The actual impact upon tax revenues is therefore an empirical question. One would have to

investigate the profit situation in specific industries to forecast the effect of tax changes in particular cases. This is about as far as it is possible to go mathematically in this area.

APPENDIX D: MATHEMATICAL APPENDIX TO CHAPTER VII

Impose on the firm set forth in B.2. a pollution function. Let the amount of pollution released in any one period, written as η_t, depend upon output, q_t, in the following way:

(16) $$\eta_t = h(q_t)$$

(17) $$\frac{d\eta_t}{dq_t} > 0$$

Let labor and capital be used in two ways. L_t^0 and K_t^0 are used to produce output $\bar{q}_t$, so that $\bar{q}_t = f\ (L_t^0, K_t^0)$; L_t^1 and K_t^1 are used to reduce pollution in the t-th period. The "production function" for for pollution reduction is

(18) $$\eta_t = \phi(L_t^1, K_t^1),$$

where

(19) $$\frac{\partial \eta_t}{\partial L_t^1} < 0 \text{ and } \frac{\partial \eta_t}{\partial K_t^1} < 0 .$$

If the government forbids the firm to emit more than $\bar{\eta}_t$ into the environment during the t-th period the firm's constraint is

(20) $$\bar{\eta}_t - h[f(L_t^0, K_t^0)] - \phi\ (L_t^1, K_t^1) = 0$$

we assume that the restriction is severe enough that the firm would pollute more than $\bar{\eta}_t$, if it were free to do so. We also assume that the profit maximizing assumption limits the firm to meeting the constraint by reducing pollution no more than that

constraint requires. Thus, the equality sign holds, $L_t = L_t^0 + L_t^1$ and $K_t = K_t^0 + K_t^1$.

The firm maximizes its present value, written as

$$PV = \sum_{t=0}^{H} \left(\frac{1}{1+r}\right)^t \{P_t f(L_t^0, K_t^0) - wL_t - (r+d)K_t + \lambda(\bar{\eta}_t - h[f(L_t^0, K_t^0) - \phi[L_t^1, K_t^1]\}, \tag{21}$$

where λ is the Lagrangian multiplier. In this case $\lambda = \partial\pi_t/\partial\bar{\eta}_t$. That is, λ represents the rate in which an increase in the constraint, the amount of pollution permitted during any one period, would change the profits earned during that period. It is logical that a reduction in the constraint (an increase in severity) would lower profits and an increase in the amount of pollution allowed would increase profits. Thus $\lambda > 0$.

The firm has four choice variables during any one period of time: L_t^0, L_t^1, K_t^0, K_t^1. The maximization of present value requires that for every period t

$$\begin{aligned}
&\text{a)} \quad \bar{\eta}_t - h(q_t) - \phi(L_t^1, K_t^1) &&= 0\\
&\text{b)} \quad P_t f_{L_t^0} - \lambda h'(q) f_{L_t^0} - w_t &&= 0\\
&\text{c)} \quad - \lambda \phi_{L_t^1} - w_t &&= 0\\
&\text{d)} \quad P_t f_{K_t^0} - \lambda h'(q) f_{K_t^0} - (r+d) &&= 0\\
&\text{e)} \quad - \lambda \phi_{K_t^1} - (r+d) &&= 0
\end{aligned} \tag{22}$$

and that the matrix [D] be associated with a negative definite quadratic from (the principal minors alternate in sign) for each period where

$$[D]= \begin{bmatrix} 0 & -h'f_{L_0} & -\phi_{L_1} & -h'f_{K_0} & -\phi_{K_1} \\ -h'f_{L_0} & [(P-\lambda h')f_{L_0L_0} - \lambda h''f_{L_0}^2] & 0 & [(P-\lambda h')f_{L_0K_0} - \lambda h''f_{L_0}f_{K_0}] & 0 \\ -\phi_{L_1} & 0 & -\lambda\phi_{L_1L_1} & 0 & -\lambda\phi L_1K_1 \\ -h'f_{K_0} & [(P-\lambda h')f_{K_0L_0} - \lambda h''f_{K_0}f_{L_0}] & 0 & [(P-\lambda h')f_{K_0K_0} - \lambda h''f_{K_0}^2] & 0 \\ -\phi_{K_1} & 0 & -\lambda\phi_{K_1L_1} & 0 & -\lambda\phi_{K_1K_1} \end{bmatrix}$$

The implications of equations (22) are discussed in Chapter VII. We dropped the t-notation for expository convenience.

To analyse the effect of changes in $\overline{\eta}$, the pollution restraint, displace equation (22), assuming $d\overline{\eta} \neq 0$, to obtain

$$(23) \qquad [D] \begin{bmatrix} d\lambda \\ dL_0 \\ dL_1 \\ dk_0 \\ dk_1 \end{bmatrix} = \begin{bmatrix} -d\overline{\eta} \\ 0 \\ \cdot \\ \cdot \\ 0 \end{bmatrix}$$

In our interpretation of the results we will use the following

notation: f_{L_0} and f_{K_0} are the marginal products of labour and capital while ϕ_{L_1} and ϕ_{K_1} are the marginal productivities of labor and capital in reducing pollution. The change in the marginal product of one input from a change in the usage of the other input in production and in pollution reduction are $f_{K_0L_0} = f_{L_0K_0}$ and $\phi_{L_1K_1} = \phi_{K_1L_1}$. The rate at which output changes pollution is h' and the change in the rate of change is h'' . We assume obviously that $h' > 0$. We also assume that the rate at which output causes pollution is either constant or changes with output. However, in practice technological factors may often lead to a rate decreasing discontinuously with increasing output. We also assume that an increase in the usage of one input increases the marginal productiveity of the other; that is

$$(24) \qquad f_{K_0L_0} > 0 \text{ and } \phi_{K_1L_1} < 0.$$

We further assume that all inputs are subject to diminishing marginal productivity. That is, as the usage of an input increases, its marginal product decreases: thus

$$(25) \qquad f_{L_0L_0} < 0,\ f_{K_0K_0} < 0,\ \phi_{K_1K_1} > 0,\ \phi_{L_1L_1} > 0$$

Recall that since L_1 and K_1 reduce pollution the marginal products, ϕ_{L_1} and ϕ_{K_1} are negative. Therefore,a decrease in productivity in reducing pollution means $\phi_{L_1L_1} = \phi_{K_1K_1} > 0$. Finally, assume, as is generally done in most models of the firm, that the production functions for output and pollution reduction are strictly concave.

All this means in the two-input case is that the inputs are subject to a diminishing marginal rate of technical substitution. This means that, while maintaining a constant level of output, if one input is decreased and the other increased, the marginal product of the increased input falls relative to the marginal product of the input that is decreased. In other words, with a constant output

$$(26)\qquad \frac{\Delta\left(\dfrac{MP_K}{MP_L}\right)}{\Delta\left(\dfrac{L}{K}\right)} > 0.$$

Strict concavity of the production functions imply that

$$(27)\qquad \begin{gathered} (f_{L_0L_0}\, f_{K_0K_0} - f^2_{L_0K_0}) > 0 \\ (\phi_{L_1L_1}\, \phi_{K_1K_1} - \phi^2_{L_1K_1}) > 0. \end{gathered}$$

Any production function that is strictly concave is also strictly quasiconcave, which implies that

$$(28)\qquad (-f^2_{L_0}\, f_{K_0K_0} + 2f_{L_0}\, f_{K_0}\, f_{L_0K_0} - f^2_{K_0}\, f_{L_0L_0}) > 0.$$

The assumptions shown in equations (27) and (28) are used below to determine the effect of changes in some of the parameters. In these solutions we will use the following notation.

$$F^* = (f_{L_0L_0}\ f_{K_0K_0} - f^2_{L_0K_0}) > 0$$

(29) $$H^* = (\phi_{L_1L_1}\ \phi_{K_1K_1} - \phi^2_{K_1L_1}) > 0$$

$$F = (-f^2_{L_0}\ f_{K_0K_0} + 2f_{L_0}\ f_{K_0}\ f_{L_0K_0} - f^2_{K_0}\ f_{L_0L_0}) > 0$$

The inequalities follow from the assumption of strict concavity. Solving equation (23) by Cramer's rule yields

(30) $$\frac{dL_0}{d\bar{\eta}} = \frac{\lambda^2 H^* h'}{D}(P - \lambda h')(f_{K_0}\ f_{L_0K_0} - f_{L_0}\ f_{K_0K_0}) > 0,$$

and

(31) $$\frac{dK_0}{d\bar{\eta}} = \frac{\lambda^2 H^* h'}{D}(P - \lambda h')(f_{L_0}\ f_{K_0L_0} - f_{K_0}\ f_{L_0L_0}) > 0.$$

Equations (30) and (31) are both positive for the following reasons. The second order conditions for profit maximization, set forth above, require that the determinant D be positive. H* is positive because of the "typical" condition that the production function (in this case the production of pollution reduction) be strictly concave. As noted above $(P - \lambda h')$, the full price of a unit of output, is positive, and, because pollution increases with increased output, h' is positive. The marginal products of labor and capital, f_{K_0} and f_{L_0}, are positive. By assumption, probably realistically, an increase in the usage of one input increases the marginal product of the other; that is, f_{L_0} and $f_{K_0L_0}$ are positive. The

assumption of diminishing marginal products of labor and capital means $f_{L_0K_0}$ and $f_{K_0K_0}$ are negative. Thus $- f_{L_0} f_{K_0K_0}$, $-f_{K_0} f_{L_0L_0}$, $f_{L_0} f_{K_0L_0}$, and $f_{K_0} f_{L_0K_0}$ are all positive.

Therefore $dL_0/d\bar{\eta}$ and $dK_0/d\bar{\eta}$ are unambiguously positive because every term on the right-hand sides of (30) and (31) is positive. This result indicates that theoretically the labor and capital used to produce output are increased when an increase in the amount of pollution allowed in a period is enacted. Productive labor and capital are reduced when the pollution restriction is tightened. This result is as expected but it could not be proven without the use of mathematics.

Since labor and capital employed both increase (decrease) from an increase (decrease) in the permissible pollution, output always varies directly with the amount of pollution allowed. Again this result was expected but was certainly not transparent when the model was first set up.

However, while the effect of changes in $\bar{\eta}$ upon output and productive labor and capital can be unambiguously determined, the effect of changes in the pollution restriction upon the resources used in pollution reduction, L_1 and K_1, and therefore upon total resource usage are in some cases not transparent.

Solving equation (23) by Cramer's rule for $dL_1/d\bar{\eta}$ and $dK_1/d\bar{\eta}$ yields

$$(32) \qquad \frac{dL_1}{d\bar{\eta}} = \frac{\lambda(\phi_{L_1} \phi_{K_1K_1} - \phi_{K_1} \phi_{L_1K_1})}{D} [(P - \lambda h')^2 F^* + \lambda h''(P - \lambda h') F]$$

and

$$(33)\quad \frac{dK_1}{d\bar{\eta}} = \frac{\lambda(\phi_{K_1}\ \phi_{L_1L_1} - \phi_{L_1}\ \phi_{K_1L_1})}{D}\ [(P - \lambda h')^2\ F^* + \lambda h''(P - \lambda h')\ F]$$

The first terms in equations (32) and (33) are unambiguously negative. Since K_1 and L_1 reduce pollution, ϕ_{K_1} and ϕ_{L_1} are both negative. Diminishing marginal productivity implies that $\phi_{L_1L_1}$ and $\phi_{K_1K_1}$ are positve; if the usage of one input increases the marginal product of the other, $\phi_{K_1L_1}$ and $\phi_{L_1K_1}$ are negative. (Recall that since L_1 and K_1 reduce pollution the marginal products, ϕ_{L_1} and ϕ_{K_1} are negative. Therefore, an increase in productivity in reducing pollution means $\phi_{L_1K_1} = \phi_{K_1L_1} < 0$. Thus $(\phi_{K_1}\ \phi_{L_1L_1} - \phi_{L_1}\phi_{K_1L_1})$ and $(\phi_{L_1}\phi_{K_1K_1} - \phi_{K_1}\phi_{L_1K_1})$ are negative. As noted above λ and D are positive. Thus the first term is negative. The sign of (32) and (33) therefore depends upon the sign of the second term.

$F^*\ (P - \lambda h')$ is positive because of the strict concavity of the production function. Likewise F is also positive because strict concavity implies strict quasi-concavity. Thus $\lambda h''(P - \lambda h')\ F$ is positive, negative or equal to zero as h'' is positive, negative or equal to zero. Now h'' is the rate at which the marginal pollution cost, $d\eta/dq$, changes with an increase in output. There are logical reasons to assume that h'' can take on any one of the three signs.

Obviously, if $h'' \leq 0$, the last term in (32) and (33) is negative or zero and therefore, either reinforces or has no effect

upon the other two terms. Thus, the two derivatives are negative. These derivatives then offset to some extent the derivatives in (30) and (31), and one cannot state unambiguously the effect of changes in allowable pollution upon total employment $(L_1 + L_0)$ or total investment $(K_1 + K_0)$. If $h'' > 0$, the last term in (32) and (33) could more than offset the first two terms, $dK_1/d\bar{\eta}$ and $dL_1/d\bar{\eta}$ might be negative. In this, possibly unrealistic, case (32) and (33) would reinforce (30) and (31), and the effect of changes in $\bar{\eta}$ on total employment and investment would be unambiguously direct. The implication of these results are discussed at length in the text.

Next assume the same production function as in the above model, $q_t = f(L_t, K_t)$, the same return on capital, the same wage rate, and a time horizon of H periods. Total pollution is a function of the rate of output in each period. We call the new total pollution function

$$(34) \qquad \eta = h(q_1, q_2, q_3, \ldots, q_n).$$

For simplicity, we will assume a constant marginal rate of pollution at all outputs over all periods. If we did not make this assumption the rate of pollution in each period would depend upon the level of output in each preceding period. This complication would make the problem almost unmanageable mathematically. We will make two other simplifying assumptions for mathematical simplicity. First the firm expects a constant input and output

price level over the horizon. Secondly, we assume that the firm waits until after its production horizon to clean up any pollution and attain the allowed level. In other words the pollution prevention function is

(35) $$\eta = \psi(L_{H+1}, K_{H+1})$$

and

(36) $$\psi_L < 0 \text{ and } \psi_K < 0.$$

As above we assume

(37) $$\psi_{LL} > 0,\ \psi_{KK} > 0,\ \psi_{LK} = \psi_{KL} < 0.$$

That is labor and capital have diminishing marginal products and the marginal products of each are increased with the usage of the other.

Under the above assumptions, the present value function to be maximized is

$$PV = \sum_{t=1}^{H+1} \frac{1}{(1+n)^t} \{Pf(L_t, K_t) - wL_t - (r+d)K_t + \ldots$$

(38) $$+ \lambda[\hat{\eta} - h(q_1, q_2, \ldots, q_H) - \psi(L_{H+1}, K_{H+1})]\},$$

where $\hat{\eta}$ is the permitted environmental level after production has ceased. First order conditions for the maximization of (38) are

$$
(39) \quad
\begin{aligned}
&\text{a)} \quad \hat{\eta} - h(q_1, q_2, \ldots, q_H) - \psi(L_{H+1}, K_{H+1}) = 0 \\
&\text{b)} \quad Pf_{L_t} - w - \lambda h' f_{L_t} = 0 \quad (t = 1, \ldots, H) \\
&\text{c)} \quad Pf_{K_t} - (r+d) - \lambda h' f_{K_t} = 0 \quad (t = 1, \ldots, H) \\
&\text{d)} \quad \frac{-w}{(1+r)^{H+1}} - \lambda \psi_{L_{H+1}} = 0 \\
&\text{e)} \quad \frac{-(r+d)}{(1+r)^{H+1}} - \lambda \psi_{K_{H+1}} = 0
\end{aligned}
$$

The second order condition must differ, however, from those of the previous model. Before, all periods were independent. Now every period and the H+1 period are interdependent. Therefore, the second order conditions are that the matrix [M] be associated with a negative definite quadratic form, where [M] is defined as

$$\begin{bmatrix}
0 & -h'f_{L_1} & -h'f_{K_1} & -h'f_{L_2} & -h'f_{K_2} & \cdots & -h'f_{L_H} & -h'f_{K_H} & -\psi_{L_{H+1}} & -\psi_{K_{H+1}} \\
-h'f_{L_1} & (P-\lambda h')f_{L_1L_1} & (P-\lambda h')f_{L_1K_1} & 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\
-h'f_{K_1} & (P-h')f_{K_1L_1} & (P-\lambda h')f_{K_1K_1} & 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\
-h'f_{L_2} & 0 & 0 & (P-\lambda h')f_{L_2L_2} & (P-\lambda h')f_{L_2K_2} & \cdots & 0 & 0 & 0 & 0 \\
-h'f_{K_2} & 0 & 0 & (P-\lambda h')f_{K_2L_2} & (P-\lambda h')f_{K_2K_2} & \cdots & 0 & 0 & 0 & 0 \\
\vdots & \vdots & \vdots & 0 & 0 & \vdots & \vdots & \vdots & \vdots & \vdots \\
-h'f_{L_H} & 0 & 0 & 0 & 0 & \cdots & (P-\lambda h')f_{L_HL_H} & (P-\lambda h')f_{L_HK_H} & 0 & 0 \\
-h'f_{K_H} & 0 & 0 & 0 & 0 & \cdots & (P-\lambda h')f_{K_HL_H} & (P-\lambda h')f_{K_HK_H} & 0 & 0 \\
-\psi_{L_{H+1}} & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & -\lambda\psi_{L_{H+1}L_{H+1}} & -\lambda\psi_{L_{H+1}K_{H+1}} \\
-\psi_{K_{H+1}} & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & -\lambda\psi_{K_{H+1}K_{H+1}} & -\lambda\psi_{K_{H+1}K_{H+1}}
\end{bmatrix}$$

If there are H+1 periods and two inputs are used in each period, a total of 2(H+1) variables is even and the determinant associated with [M] is necessarily positive from the second order maximization conditions. As would be expected, the conditions set forth in (39) are quite similar to those in the above model in which pollution was constrained in each period. Again λ is the change in present value with respect to a change in the environmental restriction, $\hat{\eta}$. Since $\psi_{L_{H+1}}$ and $\psi_{K_{H+1}}$, the marginal products of of labor and capital in pollution reduction, are assumed negative, λ is positive from (39d) and (39e).

Next let $\hat{\eta}$, the environmental constraint, change while input prices remain constant. We displace equations (39) subject to $d\hat{\eta} \neq 0$ to obtain

$$(40) \qquad [M] \begin{bmatrix} d\lambda \\ d_{L_1} \\ d_{K_1} \\ d_{L_2} \\ d_{K_2} \\ \vdots \\ dL_{H+1} \\ dK_{H+1} \end{bmatrix} = \begin{bmatrix} d\hat{\eta} \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

Note that the first H sub-determinants along the principal diagonal of M are

$$(P-\lambda h')^2 F_i^* = \begin{vmatrix} (P-\lambda h')f_{L_iL_i} & (P-\lambda h')f_{L_iK_i} \\ (P-\lambda h')f_{K_iL_i} & (P-\lambda h')f_{K_iK_i} \end{vmatrix} = (P-\lambda h')^2 (f_{L_iL_i} f_{K_iK_i} - f_{L_iK_i}).$$

The subscript i designates the i-th period. Recall that the assumption of strict concavity requires all F_i^* to be positive. Note also that the last determinant along the principal diagonal can be written

$$\lambda^2 R^* = \begin{vmatrix} \psi_{L_{H+1}\,L_{H+1}} & \psi_{L_{H+1}K_{H+1}} \\ \psi_{K_{H+1}\,L_{H+1}} & \psi_{K_{H+1}\,K_{H+1}} \end{vmatrix}$$

Strict concavity requires $R^* > 0$ also.

The system of equations in (40) can easily be solved for the change in input usage in any period:

$$(41)\qquad \frac{dL_t}{d\hat{\eta}} = \frac{h'\lambda^2 R^*}{M} (f_{K_t} f_{K_tL_t} - f_{L_t} f_{K_tK_t})(P-\lambda h')^{2H+1} \prod_{\substack{i=1 \\ i\neq t}}^{H} F_i^*. \qquad (t=1, \ldots, H)$$

$$(42)\qquad \frac{dK_t}{d\hat{\eta}} = \frac{h'\lambda^2 R^*}{M} (f_{L_t} f_{K_tL_t} - f_{K_t} f_{L_tL_t})(P-\lambda h')^{2H+1} \prod_{\substack{i=1 \\ i\neq t}}^{H} F_i^*. \qquad (t=1, \ldots, H)$$

The derivatives in (41) and (42) are clearly positive. By assumption R^*, F_i^* for all i, and h' are positive. M is positive because of maximization; $f_{L_t} f_{K_tL_t}$ and $-f_{K_t} f_{L_tL_t}$ are positive because the marginal products are positive and $f_{LL} < 0$, $f_{KL} > 0$.

Therefore, a relaxation in the end-of-horizon environmental restriction (increase in $\hat{\eta}$) causes an increase in input usage in every period. It follows then that output in every period must increase also.

The effect upon the amounts of labor and capital used to reduce pollution in the H+1 period can be easily derived from (40):

$$(43) \qquad \frac{dL_{H+1}}{d\hat{\eta}} = \frac{\lambda}{M} \left(\psi_{L_{H+1}} \psi_{K_{H+1}K_{H+1}} - \psi_{K_{H+1}} \psi_{L_{H+1}K_{H+1}}\right) \prod_{i=1}^{H} F_i^*$$

$$(44) \qquad \frac{dK_{H+1}}{d\hat{\eta}} = \frac{\lambda}{M} \left(\psi_{K_{H+1}} \psi_{L_{H+1}L_{H+1}} - \psi_{L_{H+1}} \psi_{K_{H+1}L_{H+1}}\right) \prod_{i=1}^{H} F_i^*.$$

By assumption ψ_L and ψ_K are negative. Diminishing marginal product requires ψ_{LL} and ψ_{KK} positive. If an increase in the usage of one input increases the productivity of the other $\psi_{LK} = \psi_{KL} < 0$. Therefore, from (43) and (44) an increase in the amount of pollution allowed unambiguously decreases the amount of labor and capital used to reduce pollution. The results, of course, are unambiguous since we assumed in this model that h'' = 0. Recall that in the previous solution for anti-pollution inputs we had no ambiguity when h'' was equal to zero. The implications of these results are discussed at length in the text.

APPENDIX E

DATA BANK.

Table E-1: Precious Metal Mining - Ontario: Column 1-year; column 2 - ore hoisted in thousands of tons; column 3- gross value of production in thousands of current dollars; column 4 - gross value of production in thousands of 1961 dollars (deflators from column 2, table E-4); column 5 - average annual employment= man years worked; column 6 - total direct wages and salaries paid in thousands of current dollars; column 7 - total direct wages and salaries paid in thousands of 1961 dollars (deflators from column 2, table E-4). All data from Annual Reports, Ministry of Natural Resources Ontario, Division of Mines.

Table E-2: Base Metal Mining - Ontario: Columns and sources as for Table E-1.

Table E-3: Total Metal Mining - Ontario: Columns and sources as for Table E-1.

Table E-4: Column 1 - year; column 2 - Implicit Price Indices of Gross National Expenditures: 1900-1925 U.S.A. (Canadian figures were not readily available), 1926-1972 Canada; column 3 - number of operating precious metal mines; column 4 - number of operating base metal mines, column 5 - total number of operating metal

mines. Figures for columns 3-5 from same sources as tables E-1 to E-3 (some judgement had to be exercised with respect to some mines, whether to classify them as operating during the year).

Table E-5: Canadian Metal Exports; Ores, concentrates and Scrap: column heading as shown, figures for 1973, from Statistics Canada data.

Table E-6: Canadian Metal Exports; processed: 1973; Statistics Canada data.

Table E-7: Metallic Minerals and Total Exports: 1973; Statistics Canada data.

Table E-8: Industrial Bond Yield Averages: Ontario composite data courtesy McLeod, Young, Weir & Co., Toronto

Table E-9: Canadian Price Indices: from Ontario Statistical Review.

Table E-10: Provincial Mining Taxes: in current dollars, from Mineral Resources Branch data.

Table E-11: Total Taxable Profit of Ontario Based Metal Mining Operations: in current dollars from Mineral Resources Branch data.

Table E-12: Provincial Corporate Income Taxes paid by Ontario based Metal Mining Operations: in current dollars; Mineral Resources Branch Estimates.

Table E-13: Capital and Repair Expenditures: current dollars, Statistics Canada data.

Table E-14: Breakdown of Provincial Mineral Industry Revenue: in current dollars, from Mineral Resources Branch data.

Table E-15: Variables Used for Regression Analysis of Chapter VIII: Column headings as shown; see chapter VIII for details. Derived from data in preceding tables.

Note: (The assembly of the material in Tables E 1 through E 4 was not completed until the work for Chapter VIII was completed. Smelting and refining was deducted from capital and repair expenditures data but both they and the output data still include some non-metal mining. As however even the newer series E 1 through E 4 are still in raw form, it was decided not to re-run the regressions of Chapter VIII at this stage.)

TABLE E-1: PRECIOUS METALS

1	2	3	4	5	6	7
1900	45.9	298.1	1343.	661	315.1	1419.
1901	53.4	244.4	1081.	456	242.9	1074.
1902	47.6	229.8	991.	562	270.5	1165.
1903	34.3	185.8	765.	276	125.4	516.
1904	3.1	16.1	67.	108	64.5	268.
1905	20.3	135.9	566.	165	91.4	380.
1906	18.1	1565.0	6285.	863	331.7	1332.
1907	45.3	3819.0	14521.	1066	585.1	2224.
1908	62.1	6308.0	24933.	2297	1458.9	5766.
1909	132.8	9307.5	36789.	2975	2582.3	10206.
1910	263.8	12769.4	47647.	3389	3005.6	11214.
1911	265.5	15744.0	57044.	3659	3078.3	11153.
1912	527.7	19228.2	69166.	4125	4140.4	14893.
1913	855.6	21146.3	73938.	5257	5098.3	17826.
1914	1226.7	18377.5	63153.	4882	5064.0	17402.
1915	1485.5	20367.9	71718.	5011	4602.1	16204.
1916	1875.1	23081.5	73979.	5054	5464.0	17512.
1917	1780.3	25017.2	66891.	4997	5940.6	15883.
1918	1375.6	26111.2	57261.	4368	5543.7	12159.
1919	1534.3	23396.0	45341.	4139	5485.3	10630.
1920	1658.2	24234.9	40677.	3810	6086.3	10177.
1921	2080.0	21666.2	42152.	3856	5721.3	11130.
1922	2555.3	28707.0	59931.	5414	7398.6	15445.
1923	2691.7	27347.1	55925.	5853	8954.3	18311.
1924	3298.1	32898.4	67277.	6794	10574.3	21624.
1925	3755.8	38531.8	76757.	7146	11976.2	23856.
1926	4032.3	37292.0	73992.	7676	12552.3	24905.
1927	4583.6	38787.6	77887.	7672	12687.7	25477.
1928	4490.9	36765.8	74125.	7796	12757.7	25721.
1929	4207.4	37807.4	75314.	7785	13069.0	26033.

TABLE E-1: PRECIOUS METALS

1	2	3	4	5	6	7
1930	3945.2	39561.2	81068.	8496	13426.5	27513.
1931	5219.1	47467.7	103416.	9124	15265.8	33258.
1932	5566.3	54578.8	131199.	9257	15518.6	37304.
1933	5681.7	61527.1	150802.	9056	15599.1	38233.
1934	6467.2	72423.5	174936.	11097	17979.0	43427.
1935	7086.3	78376.2	188404.	12314	20382.4	48996.
1936	7804.1	82149.8	191491.	14708	24322.5	56695.
1937	8482.7	88948.1	201696.	16075	28057.5	63622.
1938	9641.1	100076.8	227447.	18021	31582.9	71779.
1939	10778.1	110496.3	252852.	19929	35655.2	81590.
1940	11784.0	123440.7	270111.	20157	26825.5	80580.
1941	12236.6	121177.5	245796.	20948	40423.2	81994.
1942	10656.5	104913.8	203716.	16994	35116.7	68187.
1943	8074.7	100452.8	188467.	12831	26910.8	50489.
1944	6803.4	65175.2	118500.	11139	24388.9	44343.
1945	6312.5	59672.4	105990.	11206	23612.1	41939.
1946	7294.4	65598.0	113100.	13556	28796.0	49648.
1947	9691.4	67313.0	106677.	14011	32744.1	51892.
1948	8547.4	73276.6	103498.	14180	37213.9	52562.
1949	9905.8	85344.5	115487.	14420	39305.4	53187.
1950	10349.3	96114.8	127136.	14442	41372.0	54724.
1951	10326.1	95084.5	112793.	14137	43375.7	51453.
1952	10127.9	91598.0	104207.	13807	45102.6	51311.
1953	8883.9	78817.8	89770.	12706	39079.6	44509.
1954	9426.3	84443.2	94667.	12794	42717.7	47889.
1955	9769.2	91497.7	102004.	12639	43784.5	48812.
1956	9077.4	93670.2	100721.	12401	44003.0	47315.
1957	9170.1	92691.0	97570.	12498	44917.5	47281.
1958	9570.4	97727.3	101482.	12513	46129.6	47901.
1959	9422.0	95869.8	97528.	12436	47139.7	47954.

TABLE E-1: PRECIOUS METALS

1	2	3	4	5	6	7
1960	9589.5	98242.2	98736.	12525	49042.9	49289.
1961	9303.3	96232.0	96232.	11916	48476.5	48476.
1962	8682.4	94151.0	92851.	11463	47526.7	46870.
1963	8279.5	93734.8	90828.	11462	47049.0	45590.
1964	7934.9	87350.8	82562.	11355	47393.1	44794.
1965	7073.9	79788.2	73066.	9920	43514.4	39848.
1966	6211.1	69132.1	60589.	8360	40487.5	35484.
1967	5634.4	61992.8	52271.	7236	36617.1	30874.
1968	4969.3	60560.2	49477.	6182	33547.0	27407.
1969	4618.2	53401.8	41753.	5495	31282.9	24458.
1970	4019.1	46379.0	34715.	4807	29076.5	21763.
1971	3444.2	42026.3	30454.	4244	26333.4	19082.
1972	3171.1	59484.4	41251.	3745	25867.7	18744.

TABLE E-2: BASE METALS

1	2	3	4	5	6	7
1900	307.0	1188.1	5352.	1882	836.5	3768.
1901	600.5	2523.5	11166.	2644	1276.9	5650.
1902	628.8	3246.2	13992.	1833	1063.6	4584.
1903	384.1	3607.7	14847.	1827	1057.3	4351.
1904	256.6	1923.9	8016.	1163	621.0	2587.
1905	495.9	4289.0	17871.	1469	1008.0	4200.
1906	474.2	5206.4	20909.	2002	1401.2	5627.
1907	557.2	3799.7	14448.	2100	1576.1	5992.
1908	625.7	3512.0	13881.	2088	1528.9	6043.
1909	716.6	4572.4	18073.	2207	2140.0	8458.
1910	883.6	5899.5	22013.	2794	2046.3	7035.
1911	788.1	5391.5	19534.	3124	2178.6	7893.
1912	855.0	6788.9	24421.	3568	2955.6	10631.
1913	980.6	7935.8	27748.	4461	3944.0	13790.
1914	1276.3	8313.4	28568.	4482	3711.3	12753.
1915	1733.6	23742.1	83599.	5804	4629.4	16300.
1916	1900.7	31921.4	102312.	6195	6028.7	19322.
1917	1734.6	31814.7	85066.	8183	11892.4	31797.
1918	1906.4	40066.9	87866.	6128	10338.2	22671.
1919	909.4	18194.8	35261.	5115	7313.5	14173.
1920	1394.7	23956.7	40061.	5912	9062.4	15154.
1921	338.4	7111.4	13835.	3103	3140.9	6110.
1922	295.7	11583.2	24182.	1482	1827.6	3815.
1923	1236.2	16729.6	34212.	4046	4657.0	9523.
1924	1462.0	19231.9	39329.	4379	4620.0	9447.
1925	1329.8	23963.7	47737.	3677	3756.1	7482.
1926	1397.1	21926.3	43505.	3118	3520.9	6985.
1927	1403.0	23843.7	47879.	3541	4241.0	8516.
1928	1538.0	34501.2	69559.	4940	5514.1	11117.
1929	2093.0	46160.0	91952.	7707	10715.7	21346.

TABLE E-2: BASE METALS

1	2	3	4	5	6	7
1930	2168.1	43795.2	89744.	6447	9369.4	19199.
1931	1690.2	24984.8	54433.	4256	5578.2	12152.
1932	790.6	9418.2	22640.	2165	2271.3	5459.
1933	1533.9	17350.8	42527.	3670	4010.3	9829.
1934	2903.3	56849.5	137318.	5327	6994.9	16895.
1935	3608.4	64512.4	155078.	6555	8999.2	21632.
1936	4636.9	83081.7	193664.	8317	11012.8	25670.
1937	6327.9	115905.1	262823.	10468	16154.7	36631.
1938	6276.2	97828.7	222338.	9764	15219.2	34589.
1939	7973.2	99035.0	226625.	10096	15782.1	36114.
1940	8776.1	110786.5	242421.	10485	16577.9	36275.
1941	10732.7	117737.5	238819.	10870	18779.7	38092.
1942	12723.9	127726.4	248012.	12580	20241.9	39304.
1943	13505.5	105792.8	198486.	13311	24962.7	46834.
1944	13340.1	120765.6	219574.	14642	25737.3	46795.
1945	12387.1	128538.0	228309.	11681	21746.8	38626.
1946	10279.6	90893.7	156713.	8807	16844.8	29042.
1947	13307.3	140346.4	222419.	11130	24550.9	38907.
1948	13267.3	172402.4	243506.	12687	33718.2	47624.
1949	13275.6	181105.9	245069.	12812	37024.6	50100.
1950	13628.1	206425.7	273050.	14036	41133.6	54409.
1951	13937.6	272000.0	322657.	17063	55105.2	65367.
1952	17191.0	271017.4	308325.	18400	65720.6	74767.
1953	18450.0	292109.0	332698.	18649	71936.4	81932.
1954	19001.2	310741.9	348365.	18803	74009.5	82970.
1955	22093.7	379542.0	423124.	18885	76921.8	85754.
1956	25365.3	428284.4	460521.	21092	90743.5	97573.
1957	30155.3	509094.6	535889.	27440	123474.5	129973.
1958	29142.8	532117.3	552562.	29203	125304.1	130118.
1959	42592.8	710905.9	723200.	29233	146673.5	149210.

TABLE E-2: BASE METALS

1	2	3	4	5	6	7
1960	41900.8	720323.5	723943.	27514	142428.3	143144.
1961	36338.2	684552.8	684553.	24468	124951.5	124951.
1962	32990.8	635618.9	626843.	22833	118370.3	116735.
1963	31891.8	589440.5	571163.	21051	109557.7	106160.
1964	34552.4	613921.4	580266.	19278	105340.7	99565.
1965	34965.8	696243.3	637585.	23248	127785.3	117019.
1966	33438.1	663279.5	581314.	24872	136949.5	120025.
1967	38280.5	908913.2	766369.	25332	171514.8	144616.
1968	55403.5	1062396.0	867971.	23230	174589.2	142638.
1969	50354.9	947619.4	740907.	23071	161230.9	126060.
1970	61634.7	1244239.2	931317.	24147	217480.9	162785.
1971	59531.4	1208752.7	875908.	24712	234191.9	169704.
1972	53644.8	1191990.0	826623.	22514	229233.3	158969.

TABLE E-3: TOTAL METALS

1	2	3	4	5	6	7
1900	352.9	1486.2	6695.	2543	1151.6	5187.
1901	653.9	2767.9	12247.	3100	1519.8	6724.
1902	676.4	3476.0	14983.	2395	1334.1	5750.
1903	418.4	3793.5	15611.	2103	1182.7	4867.
1904	259.7	1940.0	8083.	1271	685.5	2856.
1905	516.2	4424.9	18437.	1637	1099.4	4580.
1906	492.3	6724.4	27006.	2865	1732.9	6959.
1907	602.5	7618.7	28968.	3166	2161.2	8217.
1908	687.8	9820.0	38814.	4385	2987.8	11809.
1909	849.4	13879.9	54861.	5182	4722.3	18665.
1910	1147.4	18668.9	69660.	6183	5051.9	18850.
1911	1053.6	21135.5	76578.	6783	5256.9	19046.
1912	1382.7	26017.1	93587.	7693	7096.0	25525.
1913	1836.2	29082.1	101686.	9718	9042.3	31616.
1914	2503.0	26690.9	91721.	9364	8775.3	30155.
1915	3219.1	44110.0	155317.	10815	9231.5	32505.
1916	3775.8	55002.9	176291.	11249	11492.7	36835.
1917	3514.9	56831.9	151957.	13180	17833.0	47428.
1918	3282.0	66178.1	145127.	10496	15881.9	34828.
1919	2443.7	41590.8	80602.	9254	12798.8	59253.
1920	3052.9	48281.6	80739.	9722	15148.7	25332.
1921	2418.4	28777.6	55988.	6959	8862.2	17241.
1922	2851.0	40290.2	84113.	6896	9226.2	19261.
1923	3927.9	44076.7	90136.	9899	13611.3	27834.
1924	4760.1	52130.3	106606.	11173	15194.3	31072.
1925	5085.6	62495.5	124493.	10823	15732.3	31339.
1926	5429.4	59218.3	117497.	10794	16073.2	31891.
1927	5986.6	62631.3	125766.	11213	16928.7	33993.
1928	6028.9	71267.0	143684.	12736	18271.8	36838.
1929	6300.4	83967.4	167266.	15492	23784.7	47379.

TABLE E-3: TOTAL METALS

1	2	3	4	5	6	7
1930	6113.3	83356.4	170812.	14943	22795.9	46712.
1931	6909.3	72452.5	157849.	13380	20844.0	45411.
1932	6356.9	63997.0	153839.	11472	17789.9	42764.
1933	7215.6	78877.9	193328.	12726	19609.4	48062.
1934	9370.5	129273.0	312254.	16424	24973.9	60323.
1935	10694.7	142888.6	343482.	18869	29381.6	70628.
1936	12441.0	165231.5	385155.	23025	35335.3	82366.
1937	14810.6	204853.2	464520.	26543	44212.2	100254.
1938	15917.3	197905.5	449785.	27785	46802.1	106368.
1939	18751.3	209531.3	479477.	30025	51437.3	117705.
1940	20560.1	234227.2	512532.	30642	53403.4	116856.
1941	22969.3	238915.0	484615.	31818	59202.9	120087.
1942	23380.4	232640.2	451729.	29574	55358.6	107492.
1943	21580.2	206245.6	386952.	26142	51873.5	97323.
1944	20643.5	185940.8	338074.	25781	50126.2	91138.
1945	18699.6	188210.4	334299.	22887	45358.9	80566.
1946	17574.0	156491.7	269813.	22363	45640.8	78691.
1947	22998.7	207659.4	329096.	25141	57295.0	90800.
1948	21814.7	245679.0	347004.	26867	70932.1	100186.
1949	23181.4	266450.4	360555.	27232	76330.0	103288.
1950	23977.4	302540.5	400186.	28478	82505.6	109134.
1951	24263.7	367084.5	435450.	31200	98480.9	116821.
1952	27318.9	362615.4	412532.	32207	110823.2	126078.
1953	27333.9	370926.8	422468.	31355	111016.0	126441.
1954	28427.5	395185.1	443033.	31597	116727.2	130860.
1955	31862.9	471039.7	525128.	31524	120706.3	134566.
1956	34442.7	521954.6	561242.	33493	134746.5	144888.
1957	39325.4	601785.6	633459.	39938	168392.0	177254.
1958	38713.2	629844.6	654044.	41716	171433.7	178020.
1959	52014.8	806775.7	820728.	41669	193813.2	197165.

TABLE E-3: TOTAL METALS

1	2	3	4	5	6	7
1960	51490.3	818565.7	822679.	40039	191471.2	192433.
1961	45641.5	780784.8	780785.	36384	173428.2	173428.
1962	41673.2	729769.9	719694.	34296	165897.0	163606.
1963	40171.3	683175.3	661992.	32513	156606.7	151750.
1964	42497.3	701272.2	662828.	30633	152733.8	144360.
1965	42039.7	776031.5	710652.	33168	171299.7	156867.
1966	39649.2	732411.6	641903.	33234	177437.0	155510.
1967	43914.9	970906.2	818639.	32568	208131.9	175490.
1968	60372.8	1122956.2	917448.	29412	208136.2	170045.
1969	54973.1	1001021.2	782659.	28566	192513.8	150518.
1970	65653.8	1290618.2	966032.	28954	246557.4	184548.
1971	63075.6	1250779.0	906362.	28956	260525.3	188786.
1972	56815.9	1251474.4	867874.	26259	255101.0	176907.

TABLE E-4

1	2	3	4	5
1900	22.2	18	18	36
1901	22.6			
1902	23.2			
1903	24.3			
1904	24.0			
1905	24.0			
1906	24.9			
1907	26.3			
1908	25.3			
1909	25.3			
1910	26.8	48	12	60
1911	27.6			
1912	27.8			
1913	28.6			
1914	29.1			
1915	28.4			
1916	31.2			
1917	37.4			
1918	45.6			
1919	51.6			
1920	59.8	50	10	60
1921	51.4			
1922	47.9			
1923	48.9			
1924	48.9			
1925	50.2			
1926	50.4			
1927	49.8			
1928	49.6			
1929	50.2			

TABLE E-4

1	2	3	4	5
1930	48.8	37	10	47
1931	45.9			
1932	41.6			
1933	40.8			
1934	41.4			
1935	41.6			
1936	42.9			
1937	44.1			
1938	44.0			
1939	43.7			
1940	45.7	136	7	143
1941	49.3			
1942	51.5			
1943	53.3			
1944	55.0			
1945	56.3			
1946	58.0			
1947	63.1			
1948	70.8			
1949	73.9			
1950	75.6	57	16	73
1951	84.3			
1952	87.9			
1953	87.8			
1954	89.2			
1955	89.7			
1956	93.0			
1957	95.0			
1958	96.3			
1959	98.3			

TABLE E-4

1	2	3	4	5
1960	99.5	42	42	84
1961	100.0			
1962	101.4			
1963	103.2			
1964	105.8			
1965	109.2			
1966	114.1			
1967	118.6			
1968	122.4			
1969	127.9			
1970	133.6	26	50	76
1971	138.0			
1972	144.2			

TABLE E 5

CANADIAN METAL EXPORTS, (in thousands of current $'s)

To	EUROPE		OTHER WORLD		U.S.A.		TOTAL	
From	CANADA	ONTARIO	CANADA	ONTARIO	CANADA	ONTARIO	CANADA	ONTARIO
Iron - ores and concentrates	127,466	-	30,203	-	304,329	65,386	461,998	65,386
Scrap Iron and Steel	3,696	2,003	13,844	761	18,153	12,169	35,693	14,933
Aluminium - ores, concentrates and scrap	3,149	553	3,045	551	16,472	12,195	22,666	13,299
Copper ores, concentrates and scrap	72,150	46,182	437,392	1,153	43,279	17,704	552,821	65,039
Lead ores, concentrates and scrap	10,051	121	32,992	238	3,629	1,464	46,672	1,823
Nickel ores, concentrates and scrap	287,070	285,942	54,907	50,320	99,971	98,581	441,948	434,843
Precious Metals - ores concentrates and scrap	47,777	39,494	11,447	50	28,937	15,881	88,161	55,425
Zinc - ores, concentrates and scrap	116,164	9,642	53,178	1,881	23,418	13,432	192,760	24,955
radio-active ores, concentrates	17,356	15,698	-	-	46,794	46,069	64,150	61,767
Other metals - ores concentrates and scrap	38,663	462	22,920	79	14,002	1,495	75,635	2,036
TOTAL	723,542	400,097	659,928	55,033	598,984	284,376	1,982,534	739,506

TABLE E 6

CANADIAN METAL EXPORTS, (in thousands of current $'s)

To	EUROPE		OTHER WORLD		U.S.A.		TOTAL	
From	CANADA	ONTARIO	CANADA	ONTARIO	CANADA	ONTARIO	CANADA	ONTARIO
Ferro - alloys	( )	( )	( )	( )	4,203	2,187	( )	( )
Primary Iron and Steel	( )	( )	( )	( )	41,382	12,875	( )	( )
Castings and Forgings, steel	( )	( )	( )	( )	94,557	86,139	( )	( )
Bars and Rods ,steel	( )	( )	( )	( )	27,330	23,296	( )	( )
Plate, sheet and strip steel	(54,950)	(25,839)	(63,478)	(35,673)	90,048	80,280	(475,697)	(387,741)
Railway track material	( )	( )	( )	( )	7,313	3,461	( )	( )
Other Iron and Steel and Alloys	( )	( )	( )	( )	92,436	56,649	( )	( )
Aluminium ,including alloys	76,619	817	93,475	1,462	202,862	13,034	372,956	15,313
Copper ,including alloys	255,711	122,409	46,301	11,505	215,764	39,028	517,776	172,942
Lead ,including alloys	21,520	7	5,360	1,033	18,705	2,686	46,585	3,726
Nickel ,including alloys	49,714	29,875	117,572	108,044	224,423	180,151	391,709	318,070
Precious metals ,including alloys	4,783	931	984	984	54,253	4,471	60,020	6,386
Zinc ,including alloys	33,252	215	14,760	258	154,206	49,690	202,218	50,163
Other non-ferrous metals and alloys	5,692	1,621	1,248	950	17,425	12,042	24,365	14,613
Metal fabricated basic products	10,369	5,729	23,043	11,374	125,956	66,329	159,368	83,432
TOTAL	512,610	187,443	366,221	171,283	1,370,863	632,318	2,250,694	1,052,386
GRAND TOTALS	1,236,152	587,540	1,026,149	226,316	1,969,847	916,694	4,233,228	1,791,892

TABLE E 7

METALLIC MINERALS AND TOTAL EXPORTS

To	EUROPE		OTHER WORLD		U.S.A.		TOTAL	
From	CANADA	ONTARIO	CANADA	ONTARIO	CANADA	ONTARIO	CANADA	ONTARIO
Production (in thousands of current $'s)							3,793,120	1,478,883
Exports: (in %)								
Ores, concentrates, scrap as % of production	19.3	27.1	17.4	3.7	15.8	19.2	52.3	50.0
Semi- fabricated as % of production	14.3	12.7	9.7	11.6	36.1	42.8	59.3	71.2
Total as % of production	33.6	39.8	27.1	15.3	51.9	62.0	111.6	121.2
TOTAL EXPORTS (in thousands of current $'s)	3,963,430	1,234,155	4,073,505	774,432	16,606,640	8,596,980	24,643,575	10,605,567

TABLE E - 8

INDUSTRIAL BOND YIELD AVERAGES

	AAA		AAA		AAA	ONTARIO		AAA	ONTARIO
1900	4.400	1921	5.970	1941	2.770		1961	4.350	5.47
1	4.330	2	5.100	2	2.830		2	4.330	5.71
2	4.340	3	5.120	3	2.730		3	4.260	5.26
3	4.550	4	5.000	4	2.720		4	4.400	5.51
4	4.500	5	4.880	5	2.620		5	4.490	5.64
5	4.400	6	4.730	6	2.530		6	5.130	6.30
6	4.520	7	4.570	7	2.610		7	5.510	7.07
7	4.830	8	4.550	8	2.820	3.47	8	6.180	8.05
8	4.770	9	4.730	9	2.660	3.60	9	7.030	8.89
9	4.600	1930	4.550	1950	2.620	3.50	1970	8.040	9.24
1910	4.720	1	4.580	1	2.860	3.98	1	7.390	8.52
1	4.730	2	5.010	2	2.960	4.27	2	7.210	8.34
2	4.780	3	4.490	3	3.200	4.56			
3	5.020	4	4.000	4	2.900	4.05			
4	5.020	5	3.600	5	3.060	3.93			
5	5.220	6	3.240	6	3.360	4.44			
6	5.070	7	3.260	7	3.890	5.37			
7	5.410	8	3.190	8	3.790	4.88			
8	5.910	9	3.010	9	4.380	5.63			
9	5.490	1940	2.840	1960	4.410	5.56			
1920	6.120								

APPENDIX E - 9

Non-ferrous metals selling price index and general wholesale price index for Canada (1935-39=100)

YEAR	NON-FERROUS METALS	WHOLE-SALE	YEAR	NON-FERROUS METALS	WHOLE-SALE	YEAR	NON-FERROUS METALS	WHOLE-SALE
1926	136.0	130.3	1942	107.2	123.0	1958	167.3	227.8
1927	124.4	127.3	1943	107.8	127.9	1959	174.6	230.6
1928	125.1	125.6	1944	107.8	130.6	1960	177.8	230.9
1929	134.9	124.6	1945	107.6	132.1	1961	181.6	233.3
1930	109.7	112.9	1946	108.0	138.9	1962	192.1	240.0
1931	87.9	94.0	1947	132.2	163.3	1963	197.5	244.6
1932	80.2	86.9	1948	146.9	193.4	1964	205.9	245.4
1933	87.5	87.4	1949	145.2	198.3	1965	217.6	250.4
1934	87.5	93.4	1950	159.5	211.2	1966	229.9	259.5
1935	95.7	94.4	1951	180.6	240.2	1967	240.2	264.1
1936	97.6	96.8	1952	172.9	266.0	1968	250.8	269.9
1937	107.7	107.7	1953	168.6	220.7	1969	264.0	282.4
1938	98.9	102.0	1954	167.5	217.0	1970	281.0	286.4
1939	100.0	99.2	1955	187.6	218.9	1971	260.1	289.9
1940	106.9	108.0	1956	199.2	225.6	1972	262.9	310.3
1941	107.2	116.4	1957	176.0	227.4	1973	326.4	376.9

APPENDIX E - 10

PROVINCIAL MINING TAXES FOR THE FISCAL YEARS 1953/54 TO 1972/73 INCL.

(in current dollars)

1953/54	3,924,520.63
1954/55	4,509,127.87
1955/56	6,611,508.55
1956/57	8,016,487.26
1957/58	9,611,946.20
1958/59	7,223,960.39
1959/60	12,908,668.69
1960/61	17,096,831.13
1961/62	15,444,438.85
1962/63	15,222,195.08
1963/64	10,362,296.86
1964/65	14,386,839.40
1965/66	14,889,068.38
1966/67	10,640,397.92
1967/68	16,105,637.87
1968/69	19,615,792.37
1969/70	23,890,237.86
1970/71	24,731,492.00
1971/72	13,322,700.62
1972/73	16,344,254.89
1973/74 (est.)	42,976,288.00

APPENDIX E - 11

TOTAL TAXABLE PROFIT (Ontario)

FOR YEARS 1954-1972

YEAR	TOTAL TAXABLE PROFIT
1954	57,121,126
1955	84,895,028
1956	98,056,612
1957	90,279,355
1958	69,306,399
1959	141,843,988
1960	180,960,950
1961	174,082,828
1962	96,438,113
1963	109,384,896
1964	130,095,367
1965	136,736,766
1966	111,738,225
1967	143,465,644
1968	186,355,733
1969	156,252,472
1970	168,139,411
1971	103,203,752
1972	111,107,994
1973 (est.)	365,197,613

TABLE E - 12

Provincial Corporate Income Taxes, estimated for Ontario Based Corporations Engaged in Mining.

YEAR	TAX
1944	$ 2,687,150
1945	2,458,200
1946	2,161,500
1947	3,500,000
1948	4,200,000
1949	4,200,000
1950	5,600,000
1951	7,000,000
1952	5,300,000
1953	4,900,000
1954	4,600,000
1955	7,000,000
1956	7,000,000
1957	8,800,000
1958	4,400,000
1959	7,700,000
1960	7,500,000
1961	9,900,000
1962	8,882,000
1963	9,053,000
1964	14,201,000
1965	8,987,000
1966	7,128,000
1967	10,008,000
1968	13,056,000
1969	10,215,000
1970	22,043,000
1971	10,181,000
1972	13,500,000

TABLE E - 13

Capital and Repair Expenditures - All Canada, total
Mining, smelting and refining.

($ MM CURRENT)

	CAPITAL EXPENDITURES			REPAIR EXPENDITURES			TOTAL CAPITAL AND REPAIR EXPENDITURE
	CONSTRUCTION	MACHINERY AND EQUIPMENT	TOTAL	CONSTRUCTION	MACHINERY AND EQUIPMENT	TOTAL	
1972	1,261.1	564.5	1,825.6	150.3	492.2	642.5	2,468.1
1971	1,205.3	567.2	1,772.5	143.9	479.1	623.0	2,395.5
1970	975.7	420.8	1,396.5	131.7	436.2	567.9	1,964.4
1969	936.7	392.3	1,329.0	130.3	350.8	481.1	1,810.1
1968	841.1	361.2	1,202.3	124.0	335.5	459.5	1,661.8
1967	816.8	356.9	1,173.7	86.1	283.3	369.4	1,543.1
1966	806.2	352.7	1,158.9	68.6	274.1	342.7	1,501.6
1965	617.6	177.0	794.6	60.6	245.2	305.8	1,100.4
1964	501.2	221.8	723.0	56.9	215.3	272.2	995.2
1963	382.4	183.1	565.5	44.3	180.7	225.0	790.5
1962	368.6	183.4	552.0	42.5	161.7	204.2	756.2
1961	380.8	117.9	498.7	40.2	155.3	195.5	694.2
1960	327.1	138.0	465.1	39.3	144.3	183.6	648.7
1959	286.7	108.8	395.5	34.3	116.1	150.4	545.9
1958	283.3	141.3	424.6	31.9	117.0	148.9	573.5
1957	470.3	260.7	731.0	29.9	115.4	145.3	876.3
1956	431.9	209.6	641.5	29.4	105.8	135.2	776.7
1955	282.2	128.7	410.9	23.4	86.5	109.9	520.8
1954	203.6	122.0	325.6	23.2	79.5	120.7	428.3

TABLE E - 14

BREAKDOWN OF - PROVINCIAL REVENUES FROM MINING, OIL AND GAS PRODUCERS IN ONTARIO, INCLUDING CORPORATE INCOME TAX

	1970 - 1971		1971 - 1972		1972 - 1973		Estimates 1973 - 1974	
1. Taxation:								
a) Provincial Mining Taxes	$24,731,492		$13,322,701		$16,344,101		$42,976,288E	
b) Acreage Taxation	662,492		643,044		673,804		650,000E	
c) Gas Taxation	47,698		-		-		-	
Total Taxation		$25,441,642		$13,965,745		$17,017,905		$43,626,288 E
2. Royalties:								
a) Sand and Gravel	$ 251,176		$ 447,749		$			
b) Salt	223,480		202,788		634,595			
c) Gas and Oil	63,752		141,686		86,050			
Total Royalties		$ 538,408		$ 792,223		$ 720,645		$ 750,000 E
3. Licences and Permits and Mining Leases	$ 197,484	$ 197,484	$ 250,138	$ 250,138	$ 316,919	$ 316,919		$ 300,000 E
4. Fees:								
a) Recording, Abstracts etc.	$ 604,624		$ 399,156		$ 323,995			
b) Testing	57,049		63,355					
c) Sampling & Assaying	56,651		41,666					
d) Others	19,951		35,479		152,369			
Total Fees		$ 738,275		$ 539,656		$ 476,364		$ 500,000 E
5. Corporation and Capital Tax on Mining		$22,043,000		$10,181,000		$13,500,000E		$28,500,000 E
TOTAL		$26,915,809		$15,547,762		$18,531,833		$45,176,288 E
Total Revenues:		$48,958,809		$25,728,762		$32,031,833		$73,676,288

* Excluding Provincial Corporate Income Taxes

E Estimates

TABLE E - 15

VARIABLE USED FOR ANALYSIS OF CHAPTER VIII

YEAR	Gross Value of Output ($MM) Q	Mean Wage Rate $ M/ Man year W	Weighted Price Index P	Mean interest rate = industrial bond yield average (%) R	Capital and Repairs Expenditures $MM C	Provincial corporate income Tax Rate (%) Tp	Provincial Mining Tax Rate (%) Tm	Price Deflator Pw
1956	660.9	3.880	199.2	4.44	623	7	08.2	225.6
1957	760.0	4.084	176.0	5.37	697	11	10.6	227.4
1958	801.3	4.045	167.3	4.88	440	11	10.4	227.8
1959	980.6	4.502	174.6	5.63	428	11	09.1	230.6
1960	983.1	4.673	177.8	5.56	513	11	09.4	230.9
1961	946.8	4.662	181.6	5.47	571	11	08.9	233.3
1962	913.3	4.731	192.1	5.71	615	11	15.8	240.0
1963	873.8	4.695	197.5	5.26	678	11	09.5	244.6
1964	901.6	4.935	205.9	5.51	810	11	11.1	245.4
1965	992.8	5.142	217.6	5.64	958	11	10.9	250.4
1966	957.9	5.343	229.9	6.30	1274	11	07.5	259.5
1967	1,194.5	6.258	240.2	7.07	1311	12	11.2	264.1
1968	1,355.6	7.110	250.8	8.05	1411	12	10.5	269.9
1969	1,223.4	6.757	264.0	8.89	1542	12	08.2	282.4
1970	1,590.1	8.299	281.0	9.24	1828	12	15.8	286.4
1971	1,554.1	8.803	260.1	8.52	2196	12	12.9	289.9
1972	1,534.7	8.966	262.9	8.34	2163	12	14.7	310.3